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STATE OF MONTANA

DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION

Tongue River Dam

RISK ASSESSMENT

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PRC Engineering

Planning Research Corporation

January 28, 1987

Our File: 3045/1 - DG 81/87
Subject: Tongue River Dam Risk Assessment Final Report

Montana Department of Natural Resources
and Conservation Engineering Bureau
Attention: Mr. Larry Marshall, Project Manager
1520 East Sixth Avenue
Helena, Montana 59620

Dear Mr. Marshall:

We are pleased to submit thirty (30) copies of the final report and executive summary document of the Tongue River Dam Risk Assessment. Also transmitted hereby is a set of overhead view graphics of the tables and figures contained in the executive summary.

This submittal completes our work under the terms of Contract No. WE-PRC-206 dated July 23, 1986. We appreciate the assistance and cooperation given us and our subconsultants by you and the Department staff in the performance of the study and preparation of this report. We are also grateful for the opportunity to have worked on such an exciting and rewarding study.

With best regards.

Sincerely,

Glenn S. Tarbox

Glenn S. Tarbox
Project Manager and
Divisional Vice President

Enclosures
GST/td

HELENA, MONTANA 59620

CERTIFICATE OF ENGINEER

TONGUE RIVER DAM RISK ASSESSMENT PROJECT

The technical material and data contained in this report were prepared under the supervision and direction of the undersigned, whose seals as professional engineers are affixed below.

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Chief, Planning Division
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CREDITS AND ACKNOWLEDGMENTS

We wish to acknowledge the assistance of all who contributed to this report.

Larry Marshall was Project Manager for the Department of Natural Resources and Conservation (DNRC) of the State of Montana. Also of DNRC were Richard L. Bondy, Chief, Engineering Bureau, and Glen J. McDonald, Supervisor, Project Rehabilitation Section. Richard C. Harlan participated as a special consultant to DNRC.

David S. Bowles, Ph.D., Associate Director, Utah Water Research Laboratory of Utah State University, acted as a risk assessment consultant to PRC and assisted in developing the risk model and methodologies. Terrence F. Glover, Ph.D., Director of the Economics Research Institute at Utah State University, was also a risk assessment consultant to PRC for economics and damage and life loss assessments.

For the Consultant, PRC Engineering, Glenn S. Tarbox was Project Manager and responsible for overall technical review. Yin Au-Yeung was in charge of hydrology, developing the risk model, and performing dam break analyses. Elisabeth Cohen conducted damage and life loss assessments and worked on the risk model. Conducting dam break analyses and hydrological studies was Francois Zugmeyer. Ann Moore was responsible for technical editing and coordination of production. Toni Davis was in charge of production and word processing.

TONGUE RIVER DAM

RISK ASSESSMENT

REPORT

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I. EXECUTIVE SUMMARY

A. Purpose

This section is intended to summarize the Tongue River Dam Risk Assessment Report and to serve as a briefing document for use by DNRC in making presentations to the Montana Legislature.

The spillway capacity of the Tongue River Dam is inadequate to safely pass the Probable Maximum Flood (PMF) without failing the dam. The dam, therefore, poses a high risk to downstream property and lives.

A risk assessment was performed using probability theory to evaluate a number of alternative actions that have been proposed to help mitigate the current risks. The event-system response-outcome-exposure-consequence diagram shown in Figure I-1 demonstrates the overall flow of the risk assessment process.

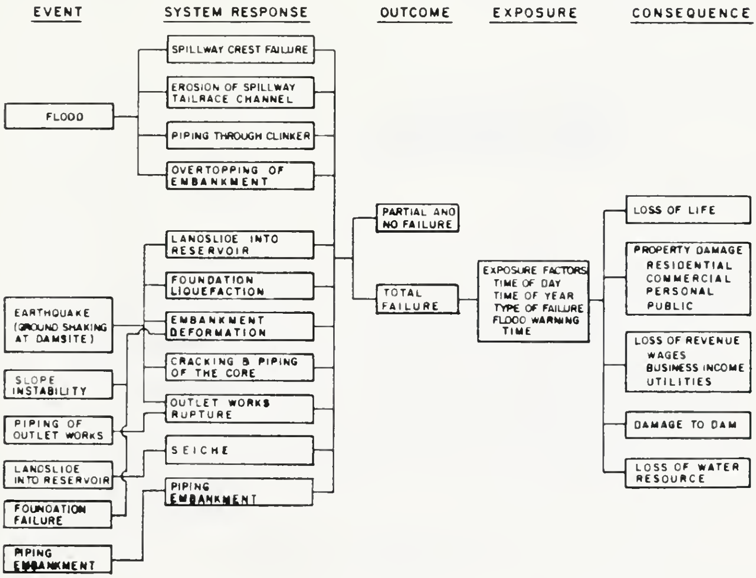


FIGURE I-1 EVENT-SYSTEM RESPONSE-OUTCOME-EXPOSURE-CONSEQUENCE DIAGRAM

The risk model used for the assessment is called an event tree and is shown in Figure I-2. The event tree depicts the sequence of events starting out from each initiating loading event to an ultimate fail/no fail outcome. The actual mathematical calculations used to quantify the risks were made using spreadsheet programs on personal computers.

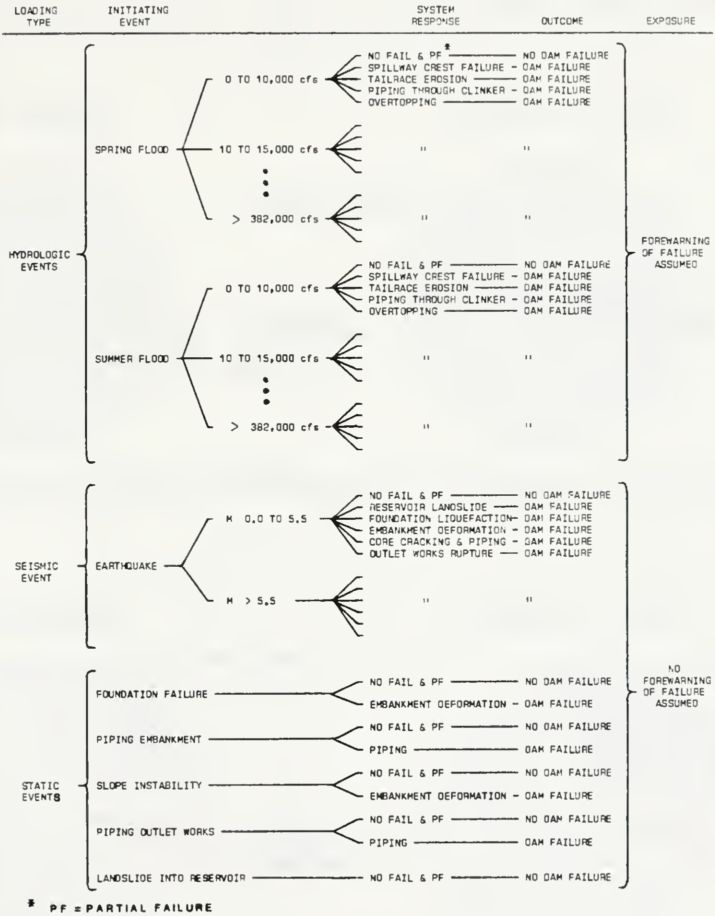


FIGURE I-2 EVENT TREE

B. Results

Analysis of Existing Dam

A breakdown of net annual risk cost and annual probability of failure by load types are shown in the pie charts in Figure I-3. The same information broken down by failure mechanism is shown in Figure I-4. These figures indicate the relative contribution to the risk of dam failure by each load type and failure mode.

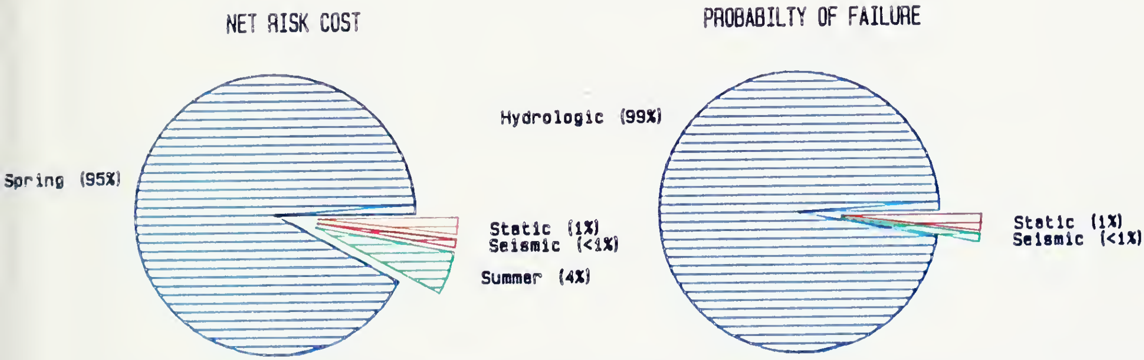


FIGURE I-3 NET RISK COST AND PROBABILITY OF FAILURE BY LOAD TYPE

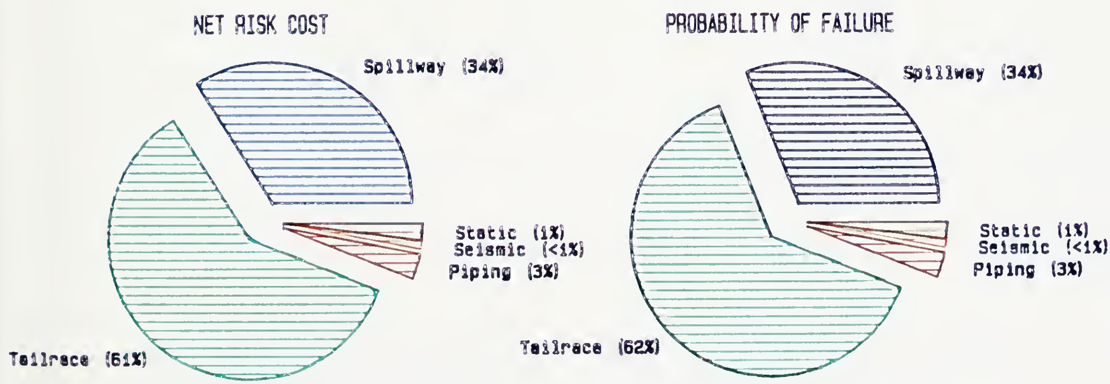


FIGURE I-4 NET RISK COST AND PROBABILITY OF FAILURE BY FAILURE MODE

Comparison of Alternative Actions

Table I-1 shows a comparison of all the alternatives in terms of construction costs, flood protection levels, estimated annual net risk costs, potential for loss of life, and other considerations.

TABLE I-1

COMPARISON OF ALTERNATIVES

	A	B	C	D	E
Construction Costs	0	$115,000,000	$51,000,000	$21,000,000	$20,000,000
Annualized Construction Costs	0	$ 10,300,000	$ 4,580,000	$ 1,920,000	$ 1,800,000
Flood Protection Level (percentage of PMF)	5	100	27	16	0
Annual Net Risk Costs	$1,610,000	$25,000	$70,000	$180,000	$0
Chance for Loss of Life	1 in 270	1 in 17,600	1 in 6,800	1 in 4,000	
Other Considerations	Does not meet Federal Dam Safety Guidelines High probability of of dam failure	New project with new benefits generated Meets Federal Dam Safety Guidelines Potential benefits to settle Indian water rights	Does not meet Federal Dam Safety Guidelines	Does not meet Federal Dam Safety Guidelines	Difficult to assess public acceptance of loss of project versus elimination of all risk due to dam failure Potential legal claims for damages and breach of contract and political controversy Loss of protection from low frequency flood

The annual risk costs and the estimated probability of life loss for each alternative are shown graphically in Figure I-5. The total annual costs (annual net risk cost plus annualized construction cost) for each alternative are plotted in Figure I-6.

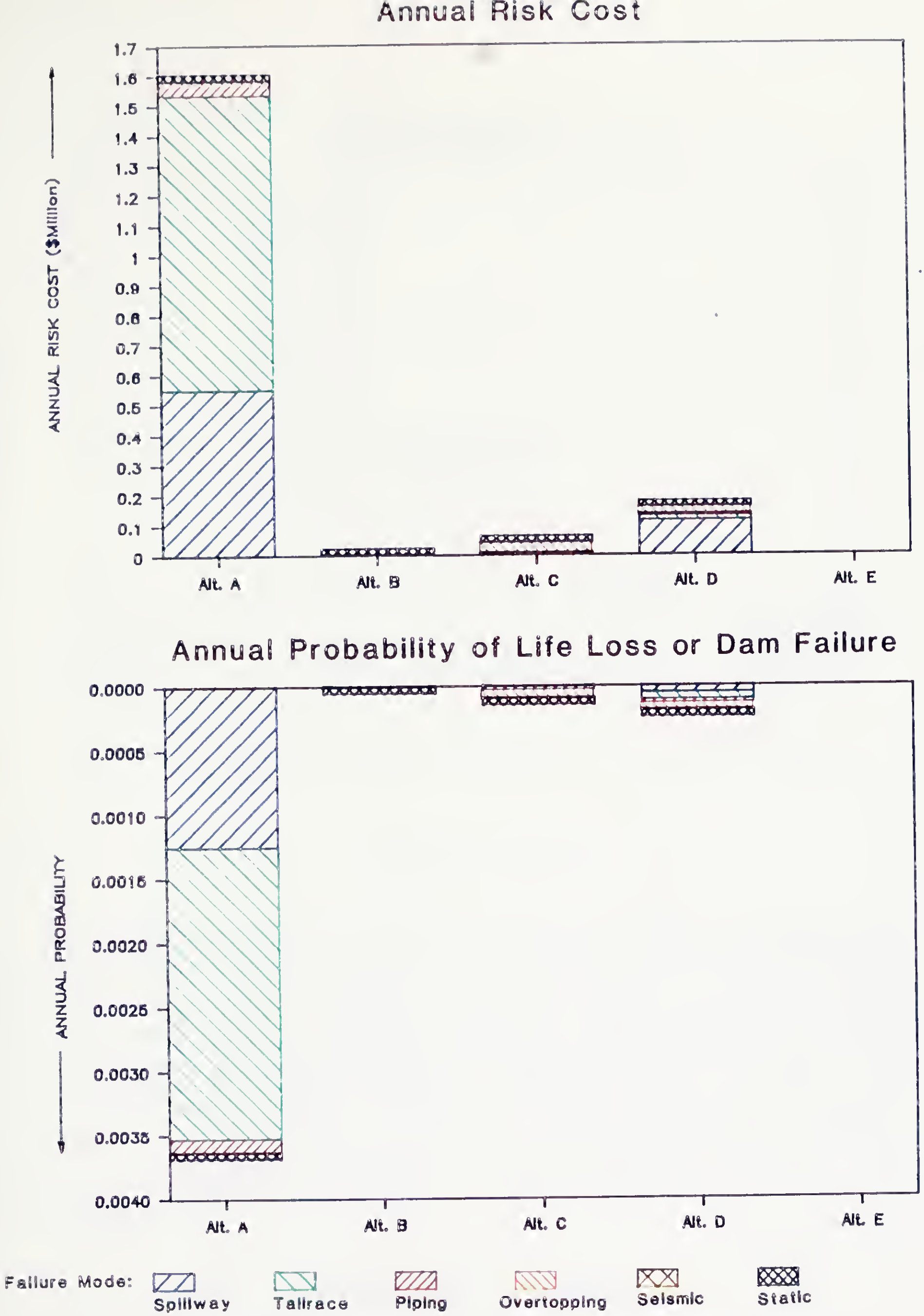


FIGURE I-5 ANNUAL RISK COSTS AND ANNUAL PROBABILITY OF LIFE LOSS OR DAM FAILURE FOR ALL ALTERNATIVES

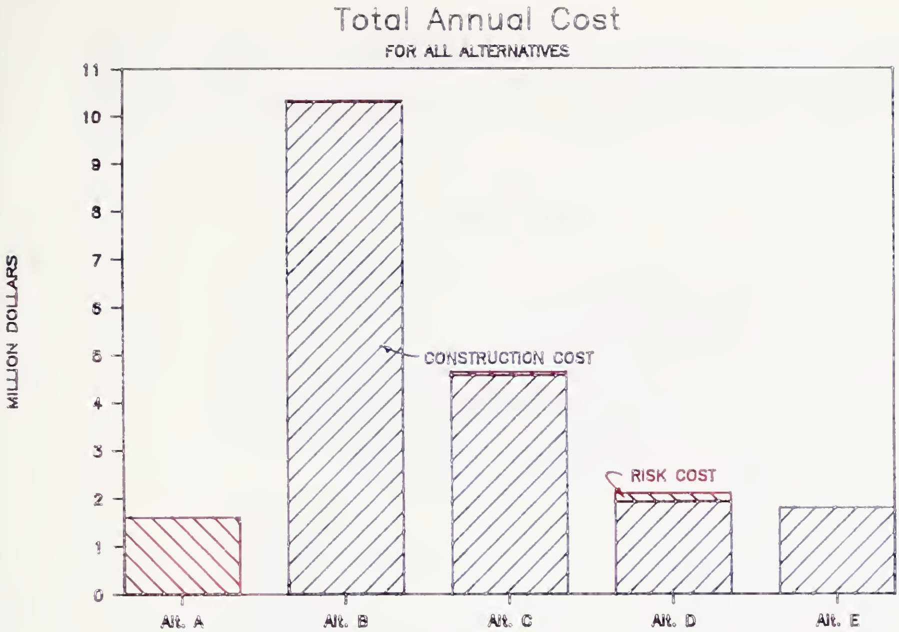


FIGURE I-6 TOTAL ANNUAL COSTS OF ALL ALTERNATIVES

Uncertainty Analysis

There is always some level of uncertainty involved in making a risk assessment. Sensitivity studies are usually made to evaluate the impact of the uncertainties on the conclusions reached from the risk assessment. The three most significant parameters of the study were return period of the PMF, economic damages, and the probability of system responses to initiating events. The results of the uncertainty analysis showed no significant change in the ranking among the alternatives. Alternative D is clearly the least cost alternative among all those which did not consider breaching the dam (Alternative E) or taking no action (Alternative A).

Comparison With Other Risks

It is useful to know how the risks of loss of life associated with the Tongue River Dam compare to other risks faced by society.

Table I-2 shows how the costs to save a life for Tongue River Dam compare to other types of regulated risks and includes a partial list of annual deaths in the United States by causes. A comparison of cost-per-life-saved is plotted in Figure I-7.

TABLE I-2
COMPARISON OF RISKS

Value	Risk
1/5,000 Years = 0.0002	Risk of Dam Failure (Involuntary)*
1 in 4,000 = .00025	Risk of Death from Auto Accident in the United States (Voluntary)*

SOURCE: Comment on Societal Risk - David Okrent - April 1980.

Energy Risk Management, G.T. Goodman & W.D. Rowe, 1979.
*Voluntary and involuntary risk values should not be compared directly.

Annual Deaths in the United States by Causes
(USBR 1983 Workshop Handout)

Causes	Number of Deaths
All Causes	1,900,000
Health Related	
Heart and Artery Diseases	800,000
Cancer	400,000
Smoking	346,000
Result of Alcohol	205,000
Stroke	170,000
Crime Related	
Violence (Homicide and Suicide)	48,000
Child Abuse	5,000
All Accidents	106,000
Motor Vehicles (Alcohol related 26,000)	52,000
Falls	14,000
Fires	6,200
Drowning	5,800
Water Transport Accidents	1,500
Flash Floods	200
Lightning	150
Tornadoes	120
Others	26,030
Dam Failure (Before 1960)	15
Dam Failure (Since 1978)	2

Examples of Cost-Per-Life-Saved Criteria

Agency or Regulatory Discipline	$ X 10^6/Life Saved
Nuclear Power Plant Design Features[2]	
Radwaste Effluent Treatment Systems	10
Containment	4
Occupational Health and Safety[1]	
OSHA[3] Coke Fume Regulations	4.5
OSHA Benzene Regulations	300
Environmental Protection[1]	
EPA[4] Vinyl Chloride Regulations	4
Automotive and Highway Safety[1]	
Seat Belts	0.08
TONGUE RIVER DAM ALTERNATIVE B	96.0
TONGUE RIVER DAM ALTERNATIVE C	34.0
TONGUE RIVER DAM ALTERNATIVE D	5.4
TONGUE RIVER DAM ALTERNATIVE E	2.1

1. From N.J. McCormick, "Reliability and Risk Analysis", 1981.
2. From E.P. O'Donnell and J.J. Mauro, "Nuclear Safety", 1979.
3. OSHA, Occupational Safety and Health Administration.
4. EPA, Environmental Protection Agency.

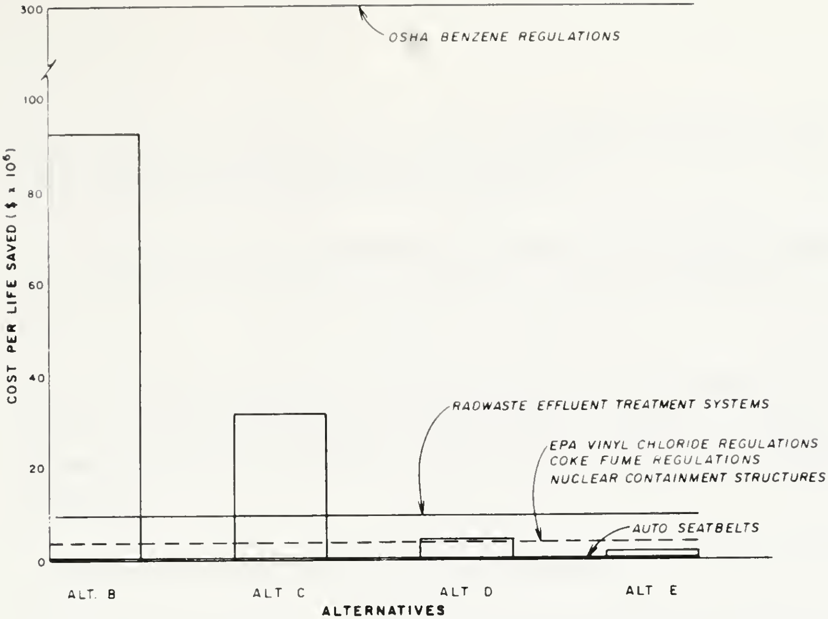


FIGURE I - 7 COST-PER-LIFE-SAVED (CPLS) FOR ALTERNATIVES COMPARED WITH SOME SELECTED CPLS FIGURES FROM OTHER PUBLIC SAFETY AREAS.

C. Conclusions

The conclusions reached in the risk assessment were as follows:

1. Because the Probable Maximum Precipitation (PMP) values developed using Hydrometeorologial Report No. 55 (HMR 55) fall within the confidence bands shown in Harza's study, the Probable Maximum Flood (PMF) developed by Harza was considered acceptable and used in this report.

Spring PMF:	
Peak Discharge	382,000 $ft.^3/s$
15-Day Volume	1,360,000 acre-feet
Summer PMF:	
Peak Discharge	108,000 $ft.^3/s$
40-Hour Volume	91,000 acre-feet

2. The largest estimated net annual risk costs and probability of failure of the existing dam are due to hydrologic loading conditions.

3. The largest net risk costs and probability of failure of the existing dam would most likely occur due to progressive failure of the spillway and stilling basin tailrace.

4. The five alternative project configurations assessed for risk and least cost in this study were selected jointly by DNRC staff and PRC from work performed previously by the Bureau of Reclamation and Harlan Miller Tait Associates.

   The alternatives investigated in this assessment included:

   A. Existing dam structure with no structural modifications and present reservoir operating restrictions removed - "Existing Dam."

   B. Modify the dam and spillway to safely pass the PMF and increase reservoir storage - "Spillway Capacity - 382,000 cfs (100% PMF)."

   C. Modify the dam and spillway to pass a 103,400 cfs flood - "Spillway Capacity - 103,400 cfs (27% PMF)."

   D. Modify the spillway and energy dissipator to pass a design capacity of 60,000 cfs (the originally intended design capacity at a water surface of El. 3437.4 based on original construction drawing No. 9 - GR dated March 14, 1938) - "Spillway Capacity - 60,000 cfs (16% PMF)."

   E. Breaching the dam and restoration of the reservoir area - "Breach."

5. Updating the Emergency Action Plan regularly and maintaining and testing the emergency warning system periodically provides the greatest protection and beneficial reduction in the risk of life loss due to flooding from dam failure.

6. Alternative A - "Existing Dam" has the least total annual cost (sum of annual net risk cost and annualized construction cost) among all the alternatives because the construction cost is zero, but has the highest annual risk cost and represents the largest risk to property downstream and lives (annual probability of life loss estimated to be 1 chance in 270).

7. Alternative B - "Spillway Capacity 382,000 cfs (100% PMF)" has the largest total annual cost among all the alternatives but has one of the smallest risks to downstream property damage and life loss (annual probability of life loss estimated to be 1 chance in 17,600).

8. Alternative C - "Spillway Capacity 103,400 cfs (25% PMF)" has the second highest total annual cost among all the alternatives and has a small risk to property and life (annual probability of life loss estimated to be 1 in 6,800).

9. Alternative D - "Spillway Capacity 60,000 cfs (16% PMF)" produces the second largest reduction in annual risk costs for the least total annual cost compared to the existing dam from among all the alternatives and had a significant reduction in the risk to property and life downstream (annual probability of life loss estimated to be 1 in 4,000).

10. Alternative E - "Breach" was the only alternative which reduced the annual risk cost to zero; but at a total annual cost exceeding that of Alternative A - "Existing Dam" (see Figure I-6) and all project benefits would be lost. The risk to life downstream due to dam failure would be reduced to zero.

11. Based on results from the uncertainty analysis which included sensitivity analyses of the flood frequencies, system responses and damage estimates, Alternative D remained the top ranked among all alternatives compared to the existing dam in maximum reduction in annual risk cost for least total annual cost, with the exception of Alternative E. This observation is a function of costs only and does not include life loss considerations (see conclusion 12).

12. The ranking of all alternatives on the basis of downstream risk to life from highest to lowest risk was Alternatives A, D, C, B, E. Although Alternative D is ranked second highest to the existing dam, Alternative A, it is evident based on Figure I-5 that the risk to life is significantly reduced between Alternative A and all the others. Therefore, Alternative D compares favorably with Alternatives B, C and E in effectively reducing the probability of life loss downstream.

13. The conclusions reached in the study and contained in this section were all predicated on the assumption that legally the State of Montana would not be liable for punitive damages and economically the state's liability would be limited to the incremental damages greater than those attributable to natural flood flow that would occur without the Tongue River dam. Any changes in the legal environment which deviate from those assumed could significantly alter the conclusions and the viability of the risk assessment approach followed. A legal opinion by DNRC legal counsel addressing this subject is contained in Appendix A.

II. INTRODUCTION

A. Authorization

This study of the Tongue River Dam was authorized under the terms of Contract No. WE-PRC-206 dated 23 July 1986 between PRC Engineering, Inc., Englewood, Colorado, and the Montana Department of Natural Resources and Conservation, Helena, Montana. Notice to Proceed was given in the letter transmitting the contract also dated 23 July 1986.

B. General

This report presents the results of a risk assessment for the Tongue River Dam. A risk assessment addresses the potential risks for a given set of conditions given the estimated frequency of loadings, the potential response of the dam to those loadings, and the potential economic damages and threat to life resulting from the combined effect of the estimated frequency of the loadings, and the potential response of the dam to those loadings.

The dam and the entire project has been studied previously with regard to improving its present condition, maintaining its present condition or increasing the present project benefits of agricultural water supply, recreation, and others. This study evaluates a range of actions to reduce the risk of dam failure in terms of a risk assessment, including the direct costs of each action alternative, the risk costs due to dam failure, and the potential for life loss.

The Tongue River Dam is located on the Tongue River approximately 10 miles north of the Montana-Wyoming border in Big Horn County as shown in Figure II-1.

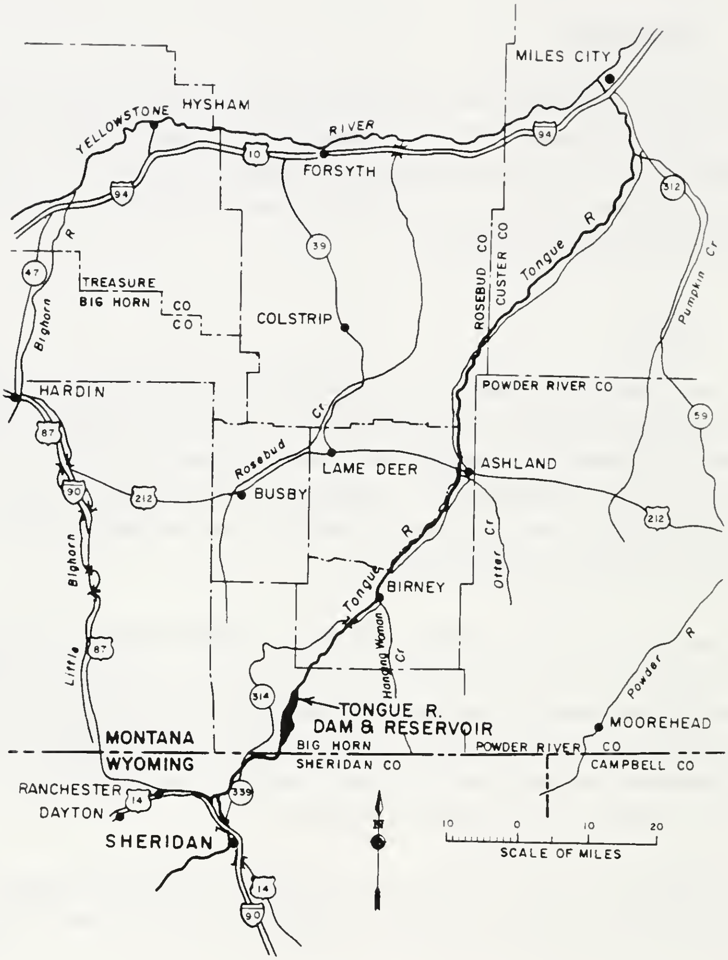


FIGURE II-1 TONGUE RIVER DAM PROJECT - MONTANA
VICINITY MAP

The dam was constructed in 1937-1938 and first operated in 1939. The embankment dam is 91 feet high, has a crest width of 54.5 feet and a crest length of 1,824 feet. The reservoir has a total capacity at the uncontrolled spillway crest of 69,400 acre-feet and a surface area of 3,500 acres. The reinforced concrete spillway is located in the left abutment and consists of a free overflow crest (crest elevation 3424.4), an open chute and a solid-type roller bucket energy dissipator. The spillway width varies from 350 feet at the crest to 100 feet at the upstream end of the energy dissipator. The existing outlet works consist of a box intake structure with trashracks and a 16-foot diameter horseshoe-shaped concrete-lined tunnel that discharges into the spillway chute at the upstream end of the energy dissipator. The maximum design discharge of the outlet works is rated at 4,300 cfs.

The dam was inspected under the National Dam Safety Program and a Phase I Inspection Report was completed. The dam has been classified as a high hazard dam due to potential loss of life in the event of a dam failure. The original spillway design flood, with a peak inflow of 96,000 cfs, is approximately 25% of the current PMF (peak inflow of 382,000 cfs). The increase in the size of the PMF, determined in a 1983 study by Harza, is due to advances in hydrologic practices and to 47 years of additional data upon which the calculations were based. In its present condition, the Tongue River Dam spillway could potentially fail for discharges of about 13,000 to 16,000 cfs (corresponding to peak reservoir inflow at 17,000 to 20,000 cfs). The project benefits would be curtailed, and most importantly there is a strong possibility of life loss.

III. BACKGROUND

A. Purpose

The firm of Harlan Miller Tait Associates has prepared several design alternatives to partially or fully rehabilitate the dam and spillway to accommodate various levels of inflow design floods, including the PMF established in 1983. The Department of Natural Resources and Conservation (DNRC) is responsible for making a recommendation to the Montana Legislature for which alternative modification is preferable. The DNRC plans to include the results of this risk assessment in its deliberations of which design alternative to recommend.

B. Philosophy of Risk Assessment

Dam engineering is not an exact science. The successful design and construction of dams requires the application of the judgement of highly experienced engineers, geologists, hydrologists, and others. Traditionally, the approach to dam design focuses deterministic analysis on extreme events, such as the probable maximum flood or the maximum credible earthquake, and uses conservative estimates of such properties as concrete or soil strengths. Safety factors are used to evaluate the ratio of resisting forces and moments to driving forces and overturning moments for structural stability. As a result, through the practice of the traditional approach, which is based on the accumulation of many decades of dam engineering experience, an impressive safety record has been achieved.

The traditional approach, however, does not attempt to explicitly quantify all significant risk factors for a dam. Nor does it explicitly determine the degree of safety, which can be justified for a particular structure, considering the potential consequences of a sudden release of the contents of a reservoir following dam failure. The risk assessment approach provides the framework to make such a quantitative determination and can provide a basis for evaluating the least cost (considering risk cost and annualized capital cost) alternative for safety improvements for an existing dam.

IV. METHOD OF ANALYSIS

A. Background

Different levels of detail in the risk assessment procedures used for dam safety evaluations are appropriate at different stages in the life of a dam. As the data base for a dam grows, and as the issues to be addressed change from general questions of site selection to specific issues of the selection of design parameters, the degree of detail, which can be justified for the risk assessment grows correspondingly (Bowles, et al., 1978; Howell, Anderson, Bowles, and Canfield, 1980). Three levels of risk assessment are generally defined. In order of increasing detail, they are the planning level, the screening level, and the design level.

At the planning level, it is advantageous to introduce an estimate of risk cost associated with dam failure into the benefit-cost analysis as a means of including societal risk into the process of deciding to build a dam (Pate-Cornell and Togaras, 1986). At this level, the estimated probabilities and consequences of dam failure are only approximate, and usually will rely heavily on historical information (U.S. Water Resources Council, 1979).

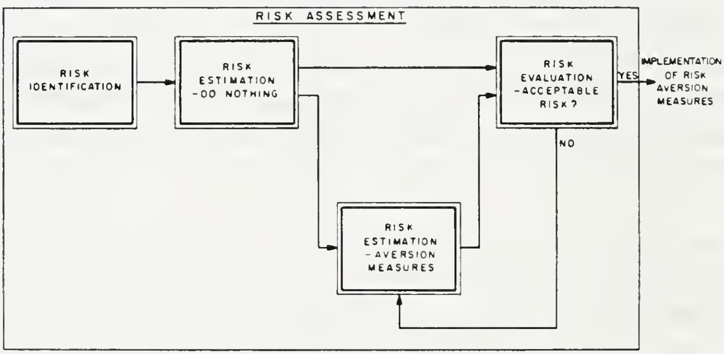
The screening level application involves the ranking of dams in order of priority for the expenditure of limited funds to pay for remedial action. In this context, the absolute values of probability and consequence estimates are less important than a consistent procedure for estimating them so that an accurate ranking will be achieved. At the screening level, site specific conditions would typically be evaluated using reconnaissance-level investigations and only approximate engineering and economic analyses (FEMA/Stanford, 1985). An example of the screening level risk assessment was the method developed for FEMA by Stanford University (McCann, et al., 1985).

A design level risk assessment involves detailed questions such as the selection of design standards and choices between design alternatives for a dam and its appurtenant structures. Carefully estimated probabilities and consequences must take into account site-specific conditions based on detailed site investigations and

engineering and economic analyses. In addition, the sensitivity of conclusions must be investigated with respect to uncertainties in the estimates of both probabilities and consequences. The only documented procedures at the design level are by the U.S. Bureau of Reclamation (1986). Work which contributed to these procedures includes Howell, Anderson, Bowles, and Canfield (1980). The design level of risk assessment was used to assess the risk posed by the Tongue River Dam.

B. Design Level Risk Assessment

There are four steps involved in a design level risk assessment as shown in Figure IV-1.



Source : Bowles (1987)

FIGURE IV-I RISK ASSESSMENT FRAMEWORK

For step one, risk identification, sequences of events are identified, beginning with events that could initiate dam failure, and ending with the consequences of the failure. Initiating events are classified as external or internal. External events include earthquakes, floods, and upstream dam failure (not applicable at Tongue

River Dam). Internal events include chemical changes in soil or concrete properties, and latent construction defects. The loading events investigated in this study are discussed in detail in Section V - Loadings.

These and other dam-reservoir system responses are failure modes which, if serious enough, can lead to the outcome of the sudden release of reservoir contents. The magnitude of the resulting property damage and life loss depends on various exposure factors. These include flood routing to determine the path and travel time of the flood wave and the area of inundation, the time of day, season of the year, and the effectiveness of the warning system and evacuation plans as discussed in Section VIII - Damage Assessment. The consequences identified in Section VIII are classified as life loss and economic loss, which include property damage, cost of dislocations, and loss of project benefits. During the identification step, professsional judgement and experience, review of available information, and a site visit were used to develop the list of initiating events, system responses, outcomes, exposure factors and consequences which apply to the Tongue River Dam-Reservoir system. A "pathways" diagram was constructed to describe these event-consequence sequences as shown in Figure IV-2.

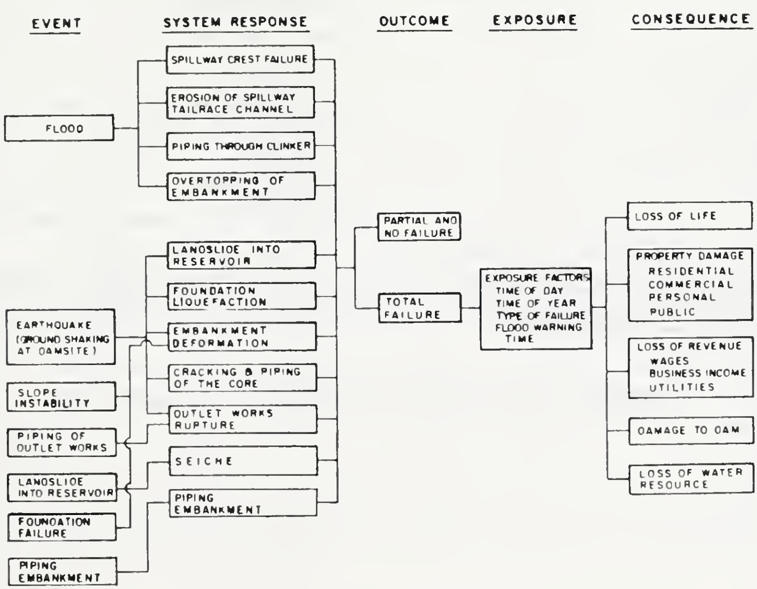
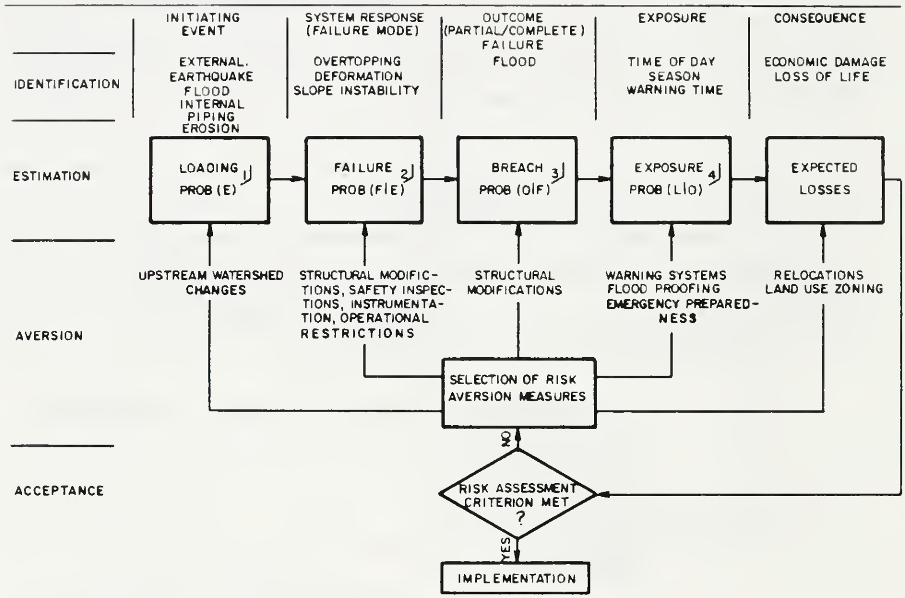


FIGURE IV-2 EVENT-SYSTEM RESPONSE-OUTCOME-EXPOSURE-CONSEQUENCE DIAGRAM

The second step, in the design level risk assessment procedure, is the estimation of the probability and consequence components of risk. The types of probabilities estimated are shown on Figure IV-3 and are as follows:



1 P(E) = ANNUAL PROBABILITY OF OCCURRENCE OF LOADING EVENT IN A RANGE OF MAGNITUDES

2 P(F/E) = CONDITIONAL RESPONSE PROBABILITY OF DAM FAILURE BY A SPECIFIC FAILURE MODE, F, GIVEN THE LOADING EVENT OCCURS

3 P(O/F) = CONDITIONAL OUTCOME PROBABILITY, O, GIVEN THAT FAILURE MODE, F, OCCURS

4 P(L/O) = CONDITIONAL LIFE LOSS PROBABILITY, L, FOR A POPULATION AT RISK GIVEN THAT OUTCOME, O, OCCURS

Source: Adapted from Bowles (1987)

FIGURE IV-3 RISK-BASED METHOD FOR DAM SAFETY IMPROVEMENTS

- o Annual probability of occurrence of loading in a range of magnitudes, E -Prob (E).

- o Conditional response probability of dam failure by a specified failure mode, F, given the loading occurs in the range, E - Prob (F/E).

- o Conditional probability of the outcome, O, release of reservoir contents, given that failure mode, F, occurs - Prob (O/F).

- o Conditional probability of life loss, L, for a population at risk (PAR) given that the outcome, O, occurs - Prob (L/O).

The probabilities determined for each loading event, system response, outcome, and life loss are discussed and tabulated on spreadsheets in Section IX - Risk Analysis Computation. Of three general approaches to probability estimation, historical/empirical, judgemental, and analytical, the historical/empirical and judgemental approaches were combined for this study.

The historical/empirical approach uses historical frequencies of events as probability estimates for the hydrological and seismic loading events. The larger the available sample size used, the better the estimate is expected to be. For the Tongue River Dam, the hydrological records are considered of relatively good quality and the details of the flood frequency determinations are presented in Section V.A -Loadings, Hydrological. The seismicity records are also of reasonably good quality and the earthquake frequency determinations are presented in Section V.B -Loadings, Seismic.

Empiricism is used in the approach for estimating the probability of failure of the dam given the various event-response probabilities based on recorded data of dam failures. These data bases have been compiled by various investigators (e.g., Bureau of Reclamation, Stanford University) and were used in this study. Because these data bases are usually small for a particular category of dam, especially large dams, and will provide only an estimate of probability of failure for "average" conditions rather than for the specific conditions at the dam, the historical/ empirical probability estimates were used as initial estimates. They were then

updated or revised based on judgement using additional specific information about the dam obtained from field work, laboratory testing, and engineering analysis performed previously by others.

The third method of probability estimation is the analytical method. For example, it can be used to derive directly calculated response probabilities for slope stability given probability distributions for strength parameters. This approach was not used for this study because, at this time, the analytical approach is generally considered to need additional research and development before it is ready for use in practical dam risk assessments.

The last tasks to be completed in step two of risk estimation are to estimate economic and life losses and to examine exposure factors. A detailed discussion of these inputs is presented in Section VIII - Damage Assessment.

The product of step two is an estimate of the probability of failure, the risk cost, and life loss that would be associated with each failure mode. If the risks are unacceptable, then Step 3 - Risk Aversion is pursued which involves developing alternatives for risk aversion. This can be accomplished by reducing the probabilities associated with a system response or outcome, or by reducing the exposure probabilities. Both structural and non-structural measures may be considered.

The product of the aversion step is an estimate of the reduction in probability of failure, the risk cost, and life loss that can be attributed to the implementation of a risk aversion measure. Such reductions are used as an estimate of the benefits of the measure, and hence, economic analyses such as least cost (sum of risk cost and cost of risk aversion measure) or a benefit-cost analysis can be performed. A discussion of the risk aversion alternatives considered in this study is presented in Section VII -Alternatives Considered. The results of the benefit-cost analysis are contained in Section X - Discussion.

The final step in the risk assessment process is the decision of how much risk is acceptable. Although the consultant has supplied information which is input to the decision making process, the actual decision must be made by the DNRC and Montana Legislature, for the State of Montana, the owner of the dam.

V. LOADINGS

Three types of loading events were analyzed. The first type of event involved dam failure due to large flood inflows. The second and third types of events concerned dam failure due to non-flood related causes, i.e., earthquake-induced failure and static failure due to internal deterioration but not associated with a flood or earthquake.

A. Hydrological

Introduction

Hydrologic loading on a dam is due to the hydrostatic and dynamic forces acting on the reservoir/spillway system during routing of the floods represented by the inflow hydrograph associated with the hydrologic event being considered. The specific type of events considered for the risk assessment were based on deficiencies at the existing Tongue River Dam and the proposed modification alternatives for the dam.

The present study was based on the concept of assessing partial risks for several load levels over the entire range of expected loading conditions. The partial risks, attributable to each loading, were summed to determine the total risk. Probabilistic hydrologic hazard analysis was performed to identify the estimated frequency of floods associated with flood loading conditions ranging up to the probable maximum flood (PMF), for use in dam response and downstream damage assessments.

In the probabilistic hydrologic hazard analysis, flood events were divided into spring and summer type events because these events are statistically independent and result from distinctly different types of meteorological and hydrological characteristics.

The spring floods in the Tongue River basin are caused by general storms over a large portion of the watershed combined with snowmelt. On the other hand, summer floods are due to local thunderstorms over a relatively small area immediately upstream from the Tongue reservoir with no runoff from snowmelt.

Flood frequency curves and Probable Maximum Floods (PMF's) for both spring and summer floods were established. The empirical flood frequency curves were extended to cover the entire range of floods up through the PMF. Annual probabilities of hydrologic loading conditions were also identified. Flood frequency study, probable maximum floods, recurrence intervals of hydrologic events, and hydrologic loading conditions are discussed in the following paragraphs.

Flood Frequency Study

Annual peak flow values for the period of 1961-1985 at USGS gaging station 06306300, located at the Tongue River at the Montana/Wyoming state line near Decker, Montana, were adjusted to obtain spring peak flows at the Tongue River Dam as shown in Table V-1. Summer peak flows at the same station 06306300 were obtained by selecting maximum flood peak values between July 15 and November 1 for each year from USGS Water Supply Papers and tabulated in Table V-2.

The Tongue River, at the state line near the Decker gage, does not contribute all the flow entering the reservoir during a storm since its drainage area is smaller than the drainage area at the Tongue River Dam. In order to account for the difference in drainage areas, the peak flows at Station 06306300 were adjusted using the equation given in Method A as shown in Table V-3:

$$\text{Adjustment} = (1{,}760/1{,}477)^{0.53} = 1.0974$$

Where, the drainage area at Tongue River Dam = 1,760 square miles and the drainage area at state line near Decker = 1,477 square miles.

TABLE V-1

SPRING FLOOD PEAKS (ft^3/s)
TONGUE RIVER AT STATE LINE NEAR DECKER, MONTANA

USGS Gaging Station 06306300

Drainage Area = 1,477 mi^2

Period of Record 1961 - 1985

1961 - 1,720	1966 - 1,920	1971 - 3,110	1976 - 2,140	1981 - 4,400
1962 - 4,560	1967 - 7,480	1972 - 2,590	1977 - 3,230	1982 - 2,570
1963 - 6,080	1968 - 5,710	1973 - 3,810	1978 - 17,500	1983 - 3,880
1964 - 5,990	1969 - 4,500	1974 - 2,900	1979 - 2,050	1984 - 4,460
1965 - 3,510	1970 - 4,190	1975 - 5,350	1980 - 2,290	1985 - 932

ESTIMATED SPRING FLOOD PEAKS (ft^3/s)
TONGUE RIVER AT TONGUE RIVER DAM

USGS Gaging Station 06306300

Drainage Area = 1,760 mi^2

1961 - 1,888	1966 - 2,107	1971 - 3,413	1976 - 2,348	1981 - 4,829
1962 - 5,004	1967 - 8,206	1972 - 2,842	1977 - 3,545	1982 - 2,820
1963 - 6,672	1968 - 6,266	1973 - 4,181	1978 - 19,205	1983 - 4,258
1964 - 6,573	1969 - 4,938	1974 - 3,182	1979 - 2,250	1984 - 4,894
1965 - 3,852	1970 - 4,598	1975 - 5,871	1980 - 2,513	1985 - 1,023

TABLE V-2

ESTIMATED SUMMER FLOOD PEAKS (ft^3/s)
TONGUE RIVER AT TONGUE RIVER DAM

At USGS Gage 06306300 (D.A. = 1,477 Sq. Miles)				At Tongue River Dam (D.A. = 1,760 Sq. Miles)	
Calendar Year	Daily Peak* (cfs)	Instant. Peak (cfs)	Date	Calendar Year	Instant. Peak (cfs)
1961	428	468	October 11	1961	513
1962	550	595	July 15	1962	653
1963	224	254	October 31	1963	279
1964	378	415	August 30	1964	456
1965	485	527	September 18	1965	579
1966	432	472	June 24	1966	518
1967	600	648	September 19	1967	711
1968	1,090	1,161	August 19	1968	1,274
1969	744	799	July 18	1969	876
1970	550	595	July 24	1970	653
1971	483	525	October 19	1971	576
1972	674	725	July 4	1972	796
1973	580	627	September 3	1973	688
1974	810	868	November 1	1974	952
1975	444	484	August 1	1975	531
1976	530	574	August 4	1976	630
1977	371	385	July 6	1977	422
1978	875	983	July 22	1978	1,079
1979	750	792	July 5	1979	869
1980	215	234	September 21	1980	257
1981	621	685	July 27	1981	752
1982	557	559	September 15	1982	613
1983	284	291	October 16	1983	319
1984	425	438	September 28	1984	481
1985	157	263	August 15	1985	289

* 1977-1985 Actual Peak Discharge Data for USGS, Helena Office.
1961-1977 Peak Discharge Data Estimated from Correlation of 1977-1985 Data.

TABLE V-3

TONGUE RIVER DAM

COMPARISON OF ESTIMATED FLOODS

Peak Discharge in Cubic Feet per Second

Annual Exceedance Probability t	$Q_{w,t}$	a	Recurrence Interval (Years)	Computational Methods A	B	C
50%	3,840	0.59	2	4,258	4,750	5,800
20%	5,510	0.58	5	6,100	5,900	7,500
10%	6,670	0.56	10	7,358	7,150	10,000
4%	8,270	0.54	25	9,091	9,100	14,500
2%	9,710	0.54	50	10,674	10,700	17,500
1%	11,400	0.53	100	12,510	12,500	20,000

Method A — Regional flood-frequency equations given in USGS Open-File Report No. 81-917.

$$Q_t = (Au/Ag)^a \times Q_{w,t}\,; \quad Au/Ag = 1{,}760/1{,}477 = 1.1916$$

where Q_t is the flood magnitude being estimated with exceedance probability t.

Au is the drainage area of Tongue Creek Dam (1,760 square miles).

Ag is the drainage area of USGS Gaging Station #06306300 (1,477 square miles) and $Q_{w,t}$ is the weighted value of the flood magnitude with exceedance probability t at Gage #06306300.

a is coefficient which is given in USGS Open-File Report No. 81-917.

Method B — Theoretical values computed from Log Pearson Type III distribution according to WRC Bulletin #17B.

Method C — Same as Method B above except that values were read off from the upper 95% confidence limit.

Flood frequency analyses were performed for both spring and summer floods for the Tongue River Dam watershed using criteria and methodology defined in Water Resource Council (WRC) Bulletin No. 17B, "Guideline for Determining Flood Frequency." Flood frequency curves for spring and summer floods are shown in Figures V-1 and V-2.

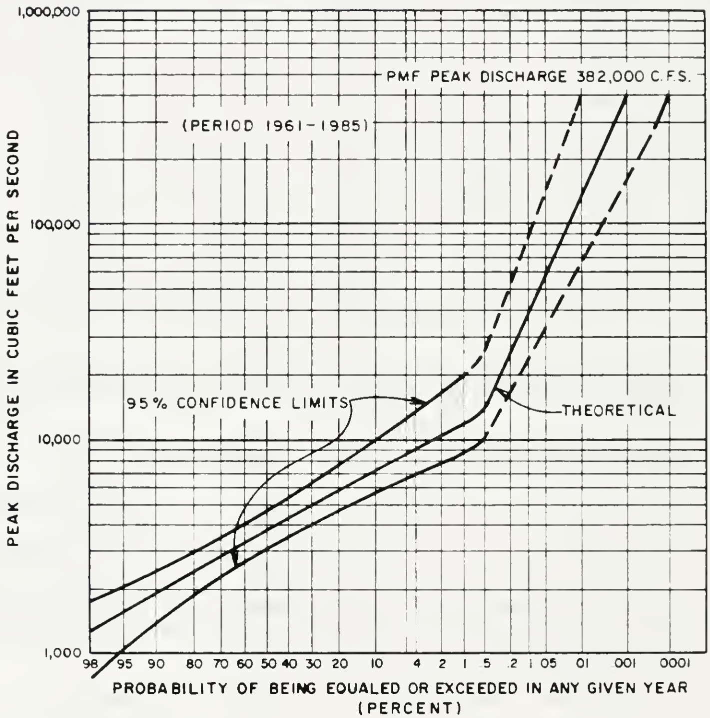


FIGURE V-1 SPRING FLOOD FREQUENCY OF TONGUE RIVER AT TONGUE RIVER DAM

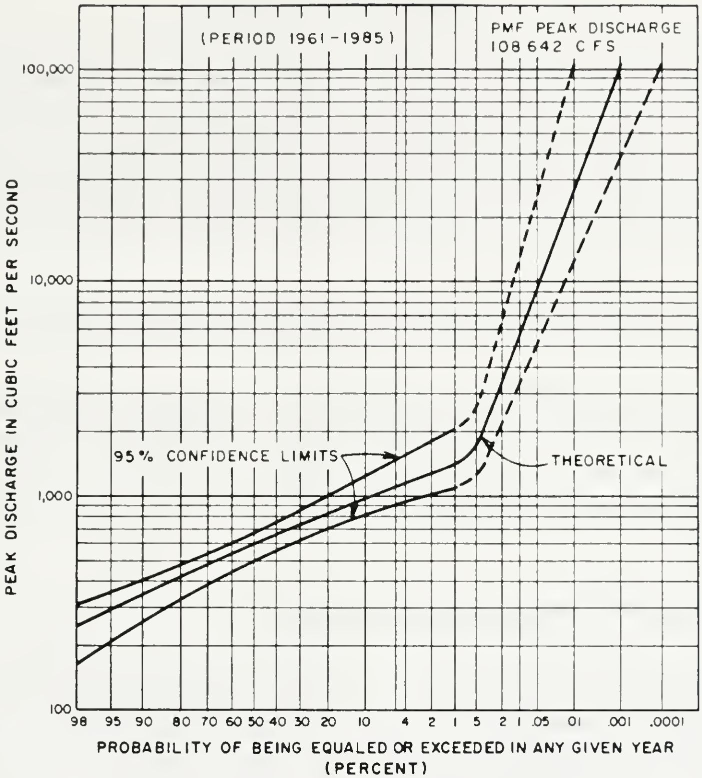


FIGURE V-2 SUMMER FLOOD FREQUENCY OF TONGUE RIVER AT TONGUE RIVER DAM

For the purpose of comparison, another flood frequency estimate was made using regional equations developed by USGS from the southeast plains region of Montana. The regional equations are published in USGS Open File Report #81-917 dated September 1984. Table V-3 shows comparison of flood frequency results computed by methods defined in Bulletin No. 17B and USGS regional equations. Results shown indicate that flood frequencies computed by Methods A and B are very similar. Results from Method C were higher than those obtained from Methods A or B because Method C is a more conservative approach.

Probable Maximum Floods

The Probable Maximum Floods (PMF's) were determined for the Tongue River Basin using the concept of regionalized PMP (Probable Maximum Precipitation) estimates. The PMP is defined by the National Weather Service as, "Theoretically the greatest depth of precipitation for a given duration that is physically possible over a given size storm area at a particular geographic location at a certain time of the year."

Basically, the estimation of the PMF's involved the following steps:

1. Estimation of PMP's for the drainage basin upstream of the Tongue River Dam in accordance with procedures given in the National Weather Service, Hydrometeorologic Report No. 55 (HMR 55), March 1984. General Storm PMP was used in developing spring PMP and Local Storm PMP for summer PMP.

2. Estimation of retention losses for the basin.

3. Derivation of Unit Hydrographs. Unit hydrographs for seven sub-basins were used in the development of spring PMF. Only the sub-basin immediately upstream from the dam was considered in the derivation summer PMF due to the nature of local storm PMP.

4. Derivation of the PMF. Unit hydrographs for each sub-basin were used with rainfall excess increments to compute sub-basin hydrographs. These sub-basin hydrographs were routed through the channel system to obtain the PMF hydrograph at the damsite due to PMP. Snowmelt and baseflow during the PMF were estimated and combined with the runoff due to PMP to obtain spring PMF hydrograph at the dam. Snowmelt was not included in the summer PMF.

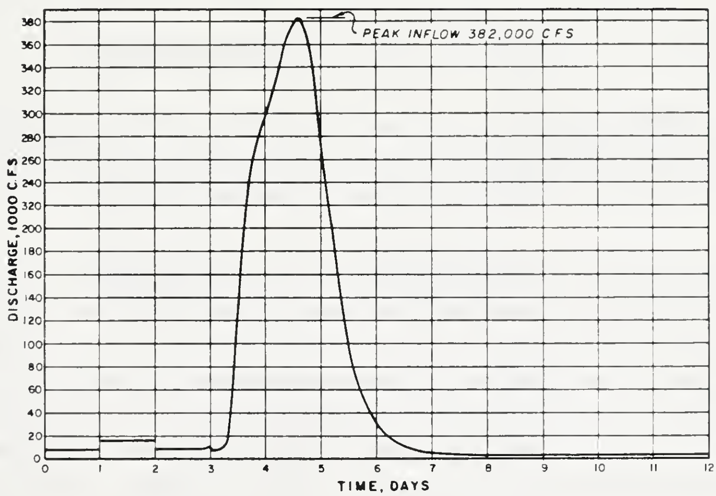
In 1983 before the publication of HMR 55, a PMF study for the Tongue River Dam was performed by Harza Engineering Company. This study was approved by the

USBR on August 11, 1983 for use in the design of the new spillway and structure of the Tongue River Dam. The PMF hydrograph developed in the Harza study is shown in Figure V-3. After review and comparison with PMP values used in the Harza study and the PMP values derived using HMR 55, the PMF developed by Harza was considered acceptable for use in this study. This judgement was based on the PMP values in the Harza study falling within the 95-percent confidence bands of the estimate of PMP based on the more recent HMR 55 procedures.

The Spring PMF hydrograph used in this study has a peak discharge of 382,000 ft^3/s and a 15-day volume of 1,360,000 acre-feet.

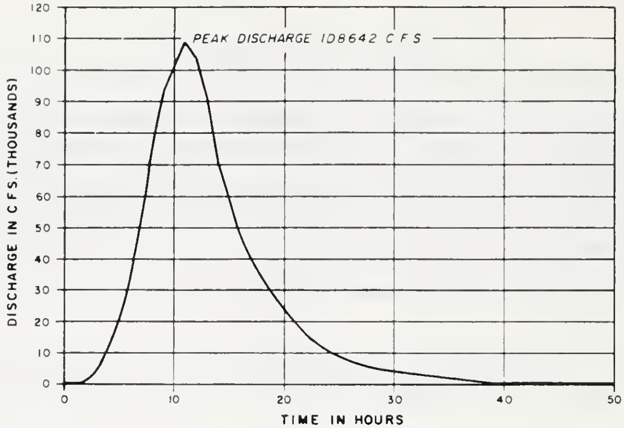
The summer PMF hydrograph for this study has a peak discharge of 108,600 ft^3/s and a 40-hour flood volume of 91,000 acre-feet.

Hydrographs for spring PMF and summer PMF are shown in Figures V-3 and V-4.



DURATION	VOLUME		
	DIRECT RUNOFF	BASE FLOW	TOTAL
(DAY)	(AF)	(AF)	(AF)
10	1,178,000	141,000	1,320,000
15	1,178,000	185,000	1,360,000

FIGURE V-3 SPRING PMF INFLOW HYDROGRAPH - TONGUE RIVER DAM



DURATION	VOLUME
40 HOURS	81,462 AF

FIGURE V-4 SUMMER PMF INFLOW HYDROGRAPH - TONGUE RIVER DAM

Recurrence Intervals of Hydrologic Events

Flood frequency relations, in accordance with WRC Bulletin No. 17B, were derived using historical flood peak data up to the 200-year return period. The development of spring and summer PMF's was discussed in preceding sections.

Risk-based analyses conducted in this study require the establishment of discharge-probability relationships for the entire range of flood events, from 10,000 ft^3/s up through PMF. Due to the lack of definite knowledge of the probability of occurrence of the PMF, the methodology suggested in USBR ACER Technical Memo No. 7 (1986) was followed to assign a probability of occurrence for flood events with return period beyond one in two hundred years. The USBR method requires the construction of frequency curves in two phases. The first portion of the curve up to a 200-year flood event (including the 95-percent confidence limit curves), using procedures outlined in Bulletin No. 17B. The portion of curve beyond the 200-year flood event was extended as straight-line extensions of the confidence

limit curves on lognormal probability paper. The straight-line extensions were from the 95-percent confidence limit curves at the 200-year event to the PMF level at assigned exceedance probabilities of 10^{-6} and 10^{-4} per year. The theoretical (median) frequency curve lies between the 95-percent confidence limit curves and is assigned an exceedance probability of 10^{-5} per year for the PMF. The complete frequency curves, covering the entire range of flood events for spring floods and summer floods are shown in Figures V-1 and V-2.

Hydrologic Loading Conditions

Selected Flood Events

Hydrologic events were divided into spring flood events and summer flood events as discussed earlier. The hydrologic events and the range of loading conditions were determined after several meetings between the consultant, Richard Harlan, (special consultant to DNRC) and DNRC staff members, including a field visit to the Tongue River Dam, Tongue River watershed, and Tongue River reaches downstream from the dam to Miles City. The hydrologic loading conditions were determined to cover a range of flood peaks from no flow over the spillway up through PMF. A total of eleven (11) levels of hydrologic loading conditions were selected in this study for the spring flood event and the summer flood event. The following are the selected 11 hydrologic loading conditions:

Hydrologic Loading Condition	Ranges of Peak Inflow (x 10^3 cfs)
1	0 to 10
2	10 to 15
3	15 to 20
4	20 to 25
5	25 to 30
6	30 to 50
7	50 to 80
8	80 to 110
9	110 to 200
10	200 to 382
11	Larger than 382

The above hydrologic loading conditions were assigned to both the spring flood event and the summer flood event for each of the rehabilitation alternatives.

Inflow Hydrographs and Annual Probability of Flood Events

The results of the flood frequency analyses, Figures V-1 and V-2, were used to determine the event probability for each flood loading condition. The theoretical frequency curves for spring floods and summer floods between the upper and lower limits are shown in Figures V-1 and V-2, respectively. Annual probability of occurrence of each flood event is presented in Table V-4.

TABLE V-4

FLOOD EVENT FREQUENCIES*

(Annual Probability)

Flood Event Peak Inflow (cfs x 10^3)	Spring Flood: High Confidence Limit	Spring Flood: Median	Spring Flood: Low Confidence Limit	Summer Flood: High Confidence Limit	Summer Flood: Median	Summer Flood: Low Confidence Limit
0 - 10	9.90×10^{-1}	9.75×10^{-1}	9.94×10^{-1}	9.99×10^{-1}	9.99×10^{-1}	9.99×10^{-1}
10 - 15	6.50×10^{-2}	1.80×10^{-2}	3.0×10^{-3}	3.0×10^{-4}	1.50×10^{-4}	4.0×10^{-5}
15 - 20	2.50×10^{-2}	4.60×10^{-3}	1.6×10^{-3}	3.0×10^{-4}	1.00×10^{-4}	4.0×10^{-5}
20 - 25	4.00×10^{-3}	8.00×10^{-4}	5.0×10^{-4}	1.0×10^{-4}	8.00×10^{-5}	1.0×10^{-5}
25 - 30	2.00×10^{-3}	8.00×10^{-4}	3.0×10^{-4}	1.0×10^{-4}	4.00×10^{-5}	1.5×10^{-5}
30 - 50	2.00×10^{-3}	8.00×10^{-4}	4.0×10^{-4}	1.0×10^{-4}	4.00×10^{-5}	8.0×10^{-6}
50 - 80	1.00×10^{-3}	3.00×10^{-4}	1.2×10^{-4}	1.5×10^{-4}	1.00×10^{-5}	5.0×10^{-6}
80 - 110	4.00×10^{-4}	1.80×10^{-4}	5.0×10^{-5}	5.0×10^{-5}	1.00×10^{-5}	1.0×10^{-6}
110 - 200	3.00×10^{-4}	8.00×10^{-5}	2.3×10^{-5}	6.0×10^{-5}	6.00×10^{-6}	6.0×10^{-7}
200 - 382	2.00×10^{-4}	3.00×10^{-5}	6.0×10^{-6}	3.0×10^{-5}	3.00×10^{-6}	3.0×10^{-7}
382	1.00×10^{-4}	1.00×10^{-5}	1.0×10^{-6}	1.0×10^{-5}	1.00×10^{-6}	1.0×10^{-7}

*Obtained by reading from Flood Frequency Curves, Figure V-1 for spring floods and Figure V-2 for summer flood.

It was necessary to develop an inflow hydrograph associated with each flood event for breach analysis and flood routing computation. The inflow hydrographs were calculated by computing a ratio of the 1978 peak for spring floods with inflow peaks less than 110,000 cfs. The hydrograph pattern was then developed using this value and the 1978 flood hydrograph as a basis. For a spring flood event larger than or equal to 110,000 cfs, the spring PMF hydrograph was used as a basis for computing the ratio and patterning of the hydrograph. The summer inflow hydrographs were calculated by prorating with the summer PMF in a manner similar to the construction of spring inflow hydrographs. For each of the rehabilitation alternatives considered, 11 inflow flood hydrographs were developed corresponding to 22 hydrologic loadings for spring and summmer floods.

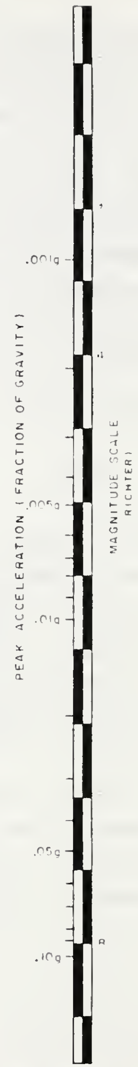
B. Seismic

Seismic loadings on the dam and its appurtenances result from ground accelerations in the foundation materials at the site due to earthquakes which occur in the vicinity. The magnitude of the load varies with ground acceleration which is a function of the earthquake magnitude and epicentral distance from the site. Both the Modified Mercalli Intensity Scale and the Richter magnitude scale are used to describe earthquakes.

The Modified Mercalli Scale is based on observed damage and human perception. It is generally based on newspaper accounts and other documented records written following an earthquake event. The Richter scale describes the seismic energy released by a fault rupture and is recorded instrumentally by strong motion accelerographs. The relationship between the two scales is shown on Figure V-5.

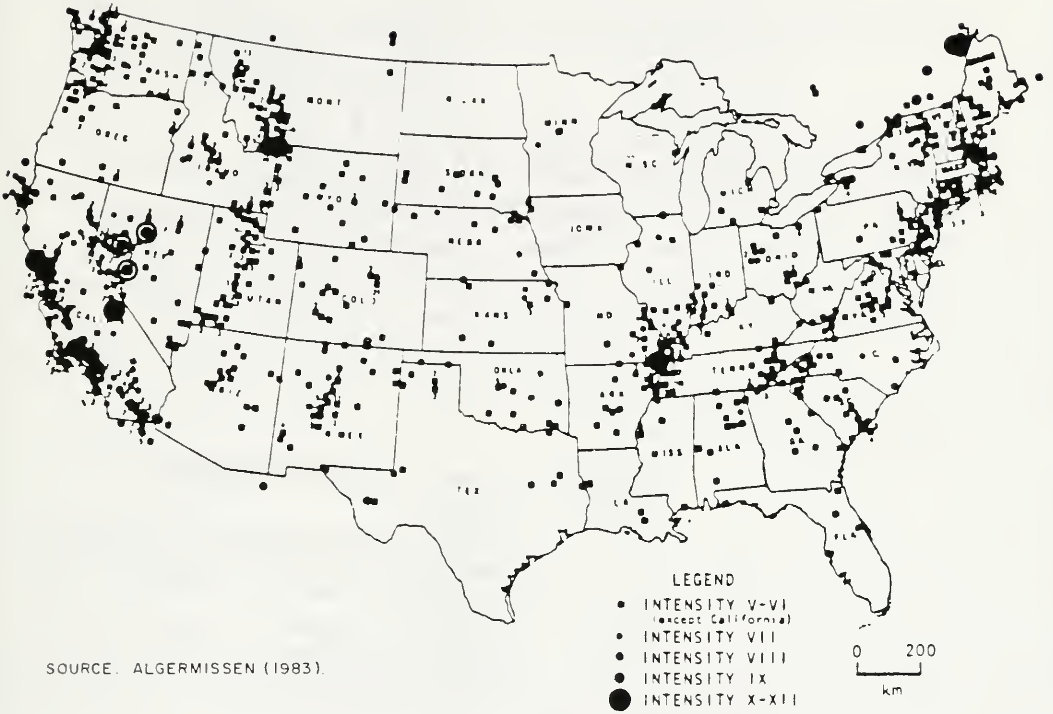
Because dams have been known to fail under seismic loads, it is important to evaluate the hazard posed by earthquakes on the dam. Examples of the types of failure modes that can occur in embankment dams include liquefaction of the dam and foundation; embankment deformation at the crest and cracking with subsequent piping of the core. The Tongue River Dam is located in a relatively quiet seismic area as evidenced by the scarcity of recorded events shown on Figure V-6.

MODIFIED MERCALLI INTENSITY SCALE	
I	Not felt. Marginal and long-period effects of large earthquakes.
II	Felt by persons at rest, on upper floors, or favorably placed.
III	Felt indoors. Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognized as an earthquake.
IV	Hanging objects swing. Vibration like passing of heavy trucks. Standing motor cars rock. Windows, dishes, doors rattle. Glasses clink. In upper range of IV wooden walls and frame creak.
V	Felt outdoors; direction estimated. Sleepers wakened. Liquids disturbed. Doors swing. Shutters, pictures move. Pendulum clocks stop, start, change rate.
VI	Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken. Books off shelves. Pictures off walls. Furniture moved or overturned. Weak plaster and adobe cracked. Small bells ring.
VII	Difficult to stand. Noticed by drivers of motor cars. Fall of plaster, loose bricks, tiles, etc. Some cracks in masonry. Waves on ponds; water turbid. Small slides, caving of sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.
VIII	Steering of motor cars affected. Damage to masonry; some partial collapse. Twisting, fall of chimneys, monuments, elevated tanks. Frame houses moved if not bolted down. Branches broken. Change in springs and wells. Cracks in wet ground and on steep slopes.
IX	General panic. Weak masonry destroyed, good masonry seriously damaged. Frame structures, if not bolted, shifted off foundations. Frames racked. Serious damage to reservoirs. Underground pipes broken. Ground cracked, sand and mud ejected, earthquake fountains, sand craters.
X	Most masonry and frame structures destroyed with their foundations. Serious damage to embankments. Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Rails bent slightly.
XI	Rails bent greatly. Underground pipelines completely out of service.
XII	Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into the air.



Source U S Bureau of Reclamation (1972)

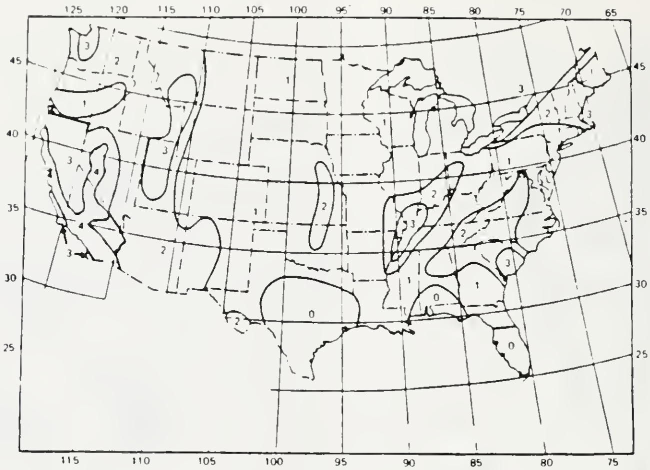
FIGURE V-5 APPROXIMATE RELATIONSHIPS: EARTHQUAKE INTENSITY, ACCELERATION, AND MAGNITUDE



SOURCE. ALGERMISSEN (1983).

FIGURE V-6 EARTHQUAKES WITH MAXIMUM MODIFIED MERCALLI INTENSITIES OF V OR ABOVE IN THE UNITED STATES THROUGH 1976

The risk to the dam of being exposed to large intensity ground shaking is also very low as shown in Figure V-7. The likelihood of seismic failure of the Tongue River Dam is very small and contributes a trivial amount to the overall risk cost. For the sake of thoroughness, however, the effect of seismic events was included in the risk assessment.



SEISMIC RISK MAP OF THE UNITED STATES

ZONE 0	No damage
ZONE 1	Minor damage distant earthquakes may cause damage to structures with fundamental periods greater 1.0 second corresponds to intensities V and VI of the MM° Scale.
ZONE 2	Moderate damage corresponds to intensity VII of the MM° Scale
ZONE 3	Major damage corresponds to intensity VIII and higer of the MM° Scale.
ZONE 4	Those areas within Zone 3 determined by the proximity to certain major fault systems

Modified Mercatal Scale of 1931.

SOURCE   REPRODUCED FROM THE UNIFORM BUILDING CODE, 1979 (1982) (1985) EDITION

FIGURE V-7 SEISMIC RISK MAP OF THE UNITED STATES

In addition to the three failure modes identified for the dam and its foundation, two other response mechanisms were also included: reservoir landslide and outlet rupture. The reservoir rim contains landslide remnants and evidence for potential

additional landslide activity. Because the outlet works passes through the dam, there is also the potential for differential movements to cause outlet pipe rupture, although the likelihood is very small.

The seismic events were broken down into three ranges, M0-4.0, M4.0-5.5, and greater than M5.5. Corresponding ranges of peak ground acceleration values were also determined as 0-0.01g, 0.01-0.08g, and greater than 0.08g. Because there was no difference in the system response for the first two ranges, they were combined into one for M0-5.5 with acceleration ranging from 0-0.08g. The magnitudes of the seismic loading events were determined by examining the historical seismicity in the near and distant region that may affect the site.

The largest historical event to occur close to the Tongue River Dam site has been an M4.0 as shown in Figure V-8.

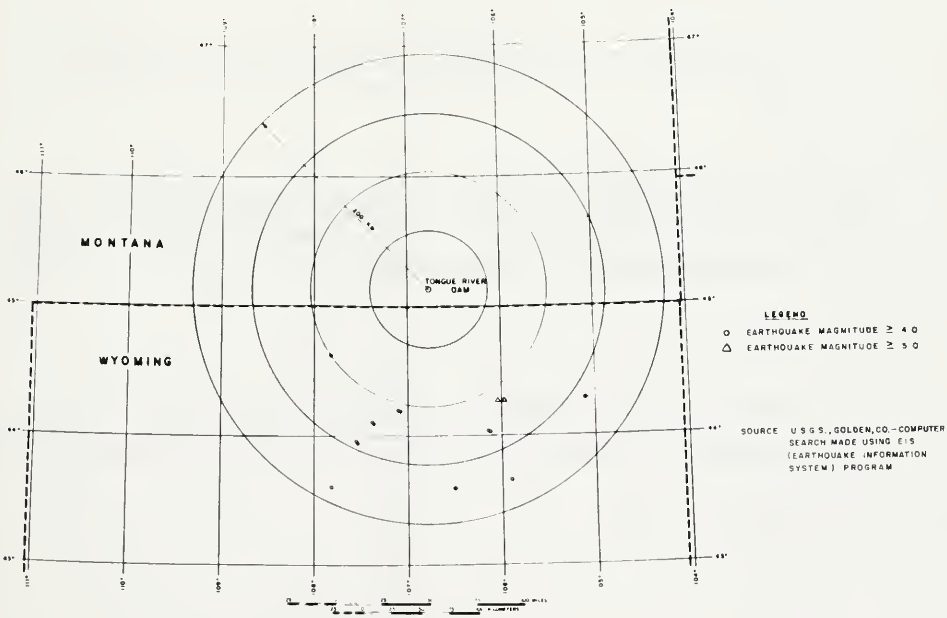


FIGURE V-8 EARTHQUAKES WITH MAXIMUM RICHTER MAGNITUDES OF 4.0 AND ABOVE WITHIN A 200 KILOMETER RADIUS OF TONGUE RIVER DAM 1900 - 1966

The other major source of any potential earthquake activity is located around the Jackson Lake, Wyoming area. The map of historic seismicity and Cenozoic faults in the Jackson Lake area, Figure V-9, was taken from a USBR report titled, "Seismotectonic Study - Jackson Lake Dam." The greater than M5.5 range was included in the list of events to account for a large magnitude event ocurring in or around the Jackson Hole area.

The acceleration range for M0-5.5 was taken from Figure V-5 and acceleration of greater than 0.08g is based on attenuating earthquakes greater than M5.5 a distance of 105 miles or greater.

The system response probabilities were rated using engineering judgement by the following groups:

1. Consultant team.

2. Richard Harlan, Consulting Engineer to DNRC for Tongue River Dam.

3. DNRC.

The final probabilities, as listed in the spreadsheets included in Section IX - Risk Analysis Computations, were reached through an iterative process of consultation based on the judgement of the members of each group.

C. Static

Static loadings on the dam, foundation, and appurtenances considered in the study were those due to normal fluctuations of the reservoir and the dead weight of the structures.

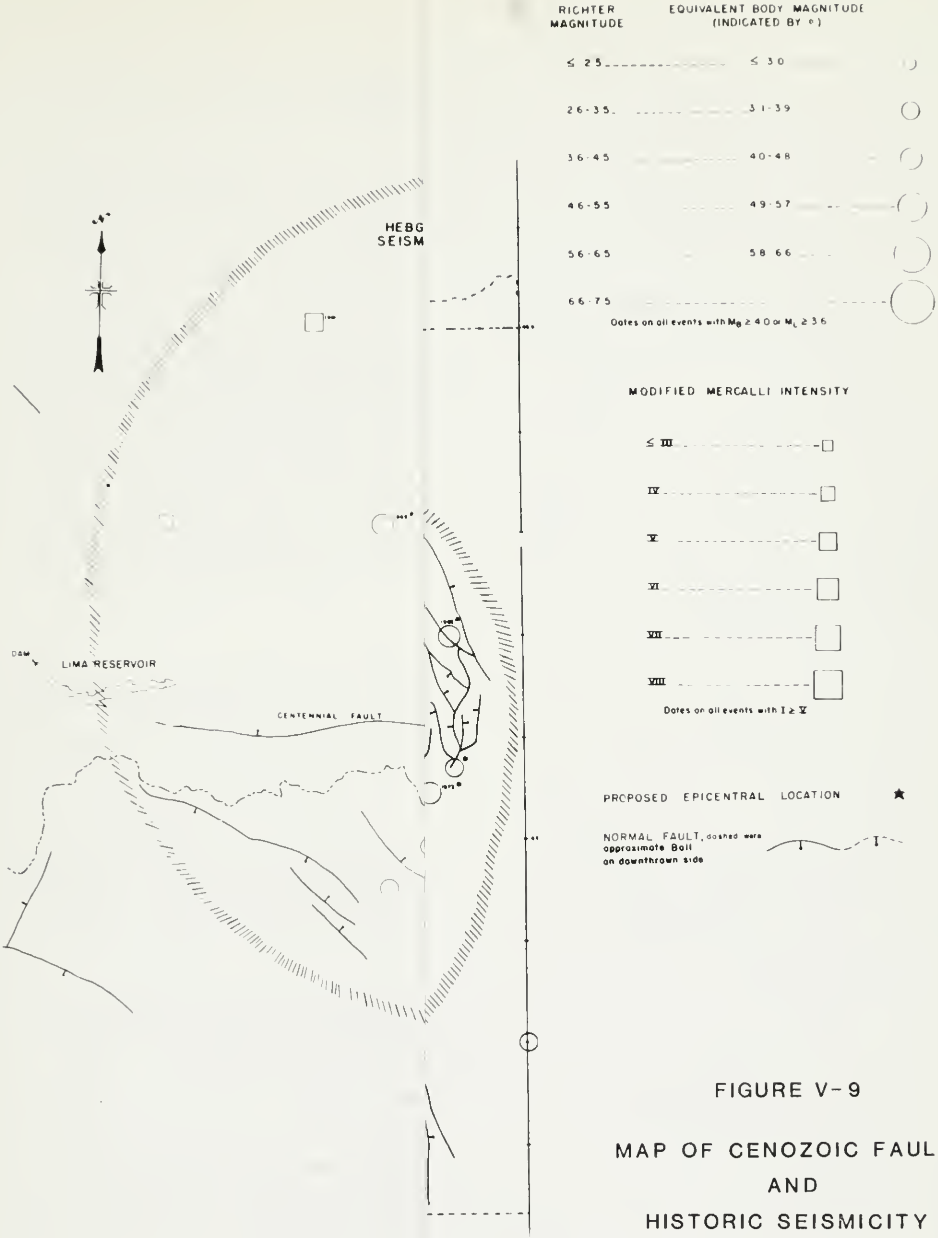


FIGURE V-9

MAP OF CENOZOIC FAULTS
AND
HISTORIC SEISMICITY
IN THE
JACKSON LAKE AREA

SOURCE: US Bureau of Reclamation (1983)

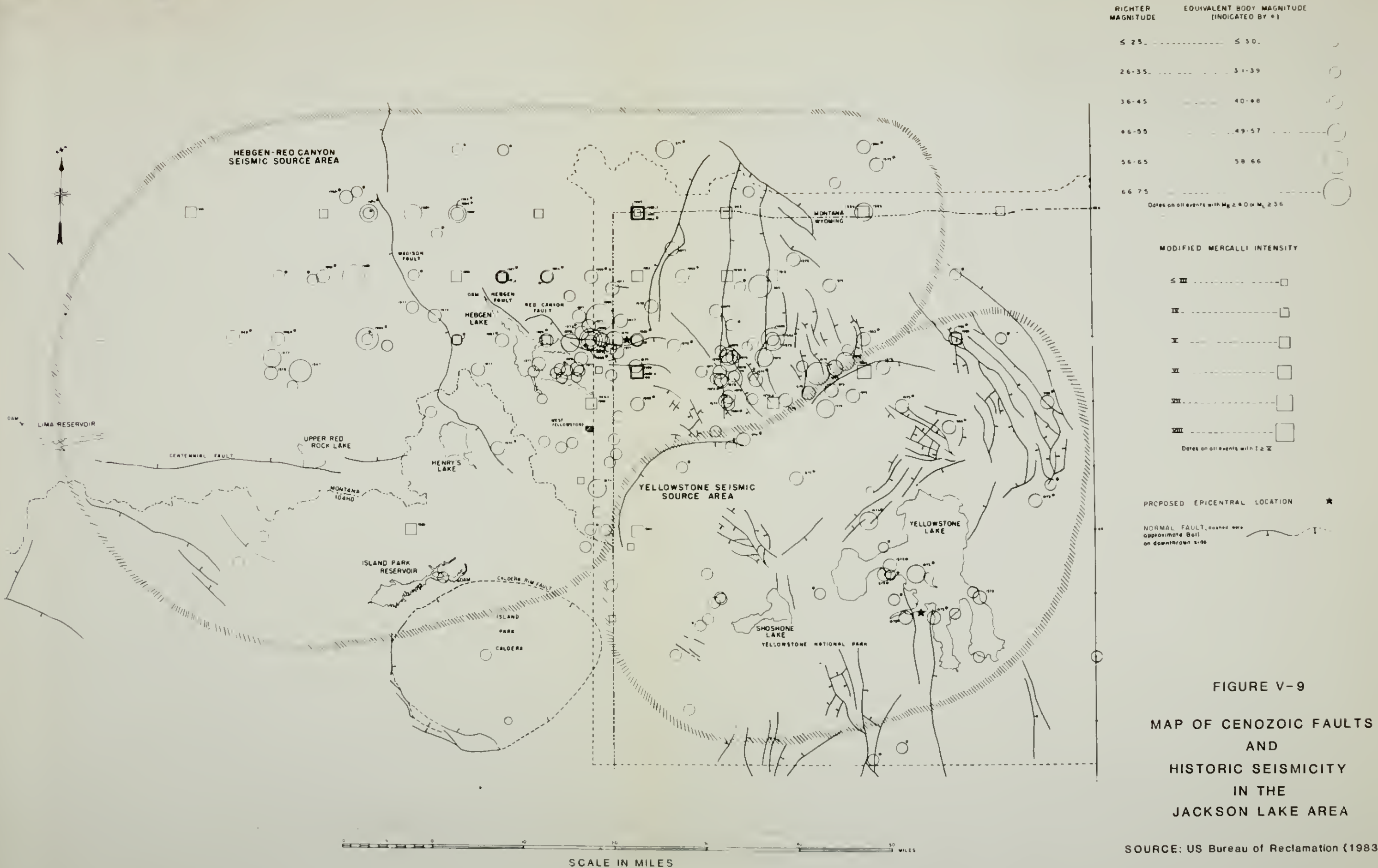


FIGURE V-9

MAP OF CENOZOIC FAULTS
AND
HISTORIC SEISMICITY
IN THE
JACKSON LAKE AREA

SOURCE: US Bureau of Reclamation (1983)

VI. EXISTING DAM STRUCTURE

It is useful to identify one of the alternatives in a risk assessment as the "reference alternative." The reference alternative is used as a basis for comparing the effect of no changes, a specific change, or a range of changes. For this study, Alternative A - Existing Dam Structure, was selected as the reference alternative. The following reports were carefully reviewed to determine the existing condition of the structure: Basic Design Report Supporting Data, State of Montana Water Resource Board, Tongue River Project, Bechtel Corporation, San Francisco 1969; Geologic and Materials Report, Tongue River Dam and Alternate Damsites, Big Horn and Rosebud Counties, Montana USBR Upper Missouri Regional Office, May 1982; and Planning Report and Preliminary Environmental Review Appendix B - Engineering, Montana Department of Natural Resources and Conservation, Tongue River Dam Study, March 1985.

The existing Tongue River Dam is located on the Tongue River about nine and one-half miles northeast of Decker, Montana. The dam is approximately 91 feet high with crest at El. 3442.4, a crest width of 54.5 feet and a crest length of 1,824 feet. The dam is owned by the State of Montana and operated by Tongue River Water Users' Association (TRWUA). It was constructed in 1937-1938 and was first operated in 1939. The reservoir has a total capacity at the spillway crest (elevation 3424.4) of 69,400 acre-feet and a surface area of 3,500 acres. The estimated capacity at the crest of the dam (elevation 3442.4) is 150,000 acre-feet.

The embankment section has a wide compacted impervious clay core flanked by a 15-foot-thick (normal to the slope) zone of dumped clinker (scoria) on the upstream 3:1 slope. The upstream toe has a berm at elevation 3384. Downstream from the impervious core is a zone of mostly sand and gravel which was spread and compacted with water in six-inch layers, then a pervious zone of alternate layers of sand and gravel, scoria and sandstone to the downstream slope of 2½:1. The toe of the downstream slope also has berms of waste material from spillway and outlet works excavation at elevations 3392 and 3384.

VI. EXISTING DAM STRUCTURE

It is useful to identify one of the alternatives in a risk assessment as the "reference alternative." The reference alternative is used as a basis for comparing the effect of no changes, a specific change, or a range of changes. For this study, Alternative A - Existing Dam Structure, was selected as the reference alternative. The following reports were carefully reviewed to determine the existing condition of the structure: Basic Design Report Supporting Data, State of Montana Water Resource Board, Tongue River Project, Bechtel Corporation, San Francisco 1969; Geologic and Materials Report, Tongue River Dam and Alternate Damsites, Big Horn and Rosebud Counties, Montana USBR Upper Missouri Regional Office, May 1982; and Planning Report and Preliminary Environmental Review Appendix B - Engineering, Montana Department of Natural Resources and Conservation, Tongue River Dam Study, March 1985.

The existing Tongue River Dam is located on the Tongue River about nine and one-half miles northeast of Decker, Montana. The dam is approximately 91 feet high with crest at El. 3442.4, a crest width of 54.5 feet and a crest length of 1,824 feet. The dam is owned by the State of Montana and operated by Tongue River Water Users' Association (TRWUA). It was constructed in 1937-1938 and was first operated in 1939. The reservoir has a total capacity at the spillway crest (elevation 3424.4) of 69,400 acre-feet and a surface area of 3,500 acres. The estimated capacity at the crest of the dam (elevation 3442.4) is 150,000 acre-feet.

The embankment section has a wide compacted impervious clay core flanked by a 15-foot-thick (normal to the slope) zone of dumped clinker (scoria) on the upstream 3:1 slope. The upstream toe has a berm at elevation 3384. Downstream from the impervious core is a zone of mostly sand and gravel which was spread and compacted with water in six-inch layers, then a pervious zone of alternate layers of sand and gravel, scoria and sandstone to the downstream slope of 2½:1. The toe of the downstream slope also has berms of waste material from spillway and outlet works excavation at elevations 3392 and 3384.

A foundation cutoff trench was constructed beneath the impervious fill. The cutoff depth varies to approximately 60 feet deep. Across the main channel, it was constructed down to a gray sandstone and has apparently been fairly effective, but on both abutments and under the spillway, it was terminated in the higher shales and seamy sandstones and it has been less effective. Beneath the downstream pervious section, a drain trench was constructed.

The existing outlet works consists of a box intake structure with trashracks and a 16-foot-diameter horseshoe-shaped, concrete-lined tunnel that discharges into the spillway chute at the upstream end of the energy dissipator. Discharge is controlled by two 6-foot by 12-foot tractor-type slide gates, one serving as the regulating gate and the other as an emergency gate. The gates are attached to cables and operated by motor-driven hoists in the control house on the dam crest. In the event of power failure, the gates may be operated by a hand crank. The maximum design discharge of the outlet works is rated at 4,300 cfs.

Repairs to the outlet works completed in 1975 included patching the floor and replacing severely pitted steel liners on the walls at the upstream end of the transition. Cavitation damage reportedly occurs when the outlet works operate around 800 ft^3/s and results from a poorly designed gate-to-tunnel transition and inadequate aeration. An 8-inch-diameter air vent is currently provided.

The existing spillway structure and its foundation have been a major concern throughout the life of the dam. The reinforced concrete spillway is located in the left abutment and consists of a free overflow crest (crest elevation 3424.4), an open chute, and a solid-type roller bucket energy dissipator. The spillway width varies from 350 feet at the crest to 100 feet at the upstream end of the energy dissipator.

Because the spillway chute width decreases so sharply, coupled with insufficient slope, it has poor hydraulic characteristics. During operation, large waves may be generated which could overtop the side walls. The spillway design capacity is reported to be about 69,000 ft^3/s at reservoir water surface elevation 3439 which is the top of the existing spillway walls.

The spillway is underlain by coal and clinker beds which have caused seepage problems in the past. Since original construction, a grout curtain, sheet piles, drain holes, and an impervious blanket have been provided to mitigate the seepage problem. Major structural repairs to the spillway were required after the May 1978 flood, when the spillway passed about 6,800 ft^3/s. The repairs included backfilling large voids behind the wing walls at the downstream end of the chute and constructing an anchored concrete overlay. Riprap was placed in the stilling basin and the area was regraded.

At the present time, the spillway floor shows evidence of differential settlements and cracking. Spalling of concrete has taken place at the tops of walls at expansion joints, exposing reinforcement steel in a few areas; however, these areas have been repaired and a maintenance program has been instituted. The placement of earthfill in the approach channel near the spillway crest has reduced the crest height from seven feet to less than three feet. The reservoir is operated at a low level to reduce the chance of spillway operation due to structural and hydraulic deficiencies.

Seepage has also been of concern in other areas besides the spillway. These include the right abutment downstream from the dam, the old river channel at the downstream toe of the dam, and a boggy area near the right side of the valley behind the damtender's house. Despite attempts to reduce seepage, it has not been totally controlled. High reservoir heads aggravate these areas of seepage. Although these areas are known to exist, they were not considered serious enough or a significant threat to dam safety. Therefore, they were not included in the risk assessment model.

VII. ALTERNATIVES CONSIDERED

The alternatives studied in this report were identified from previously prepared alternatives contained in information supplied by and with the approval of DNRC. The Tongue River Dam has previously been studied and a great deal of information has been compiled. The alternatives presented in this report and their construction costs were defined and prepared by Harlan Miller Tait Associates, the Bureau of Reclamation, and DNRC. The alternatives were approved for this study by DNRC and studied to define their relative advantages and disadvantages within the framework of the risk assessment. The choice of alternatives was selected to reflect the widest range of alternatives available at the Tongue River Dam, from removal of the dam to rehabilitating the dam to safely pass the full PMF.

The alternatives investigated in this assessment include:

A. Existing dam structure with no structural modifications and present reservoir operating restrictions removed - "Existing Dam."

B. Modify the dam and spillway to safely pass the PMF and increase reservoir storage - "Spillway Capacity - 382,000 cfs (100% PMF)."

C. Modify the dam and spillway to pass a 103,400 cfs flood - "Spillway Capacity - 103,400 cfs (27% PMF)."

D. Modify the spillway and energy dissipator to pass a design capacity of 60,000 cfs (the original intended design capacity at a water surface of El. 3437.4 based on original construction drawing No. 9 - GR dated March 14, 1938) - "Spillway Capacity - 60,000 cfs (16% PMF)."

E. Breaching the dam and restoration of the reservoir area - "Breach."

Evaluating the relative advantages and disadvantages of each alternative requires an understanding of how each alternative would be expected to respond to a given

loading event. The reaction of the structure is defined as the system response and it is conditional upon the particular loading event applied. The risk model as shown in the event tree (Figure VII-1) shows the system responses. The probability of a particular system response was determined through an iterative process of consultation using the engineering experience and judgement of the DNRC staff and its consultant, and PRC and its consultants.

The system responses and associated probabilities of each alternative are discussed below. It was determined that the system responses and the probabilities of all alternatives, due to static and seismic loading, were the same except Alternative E - Breach. The system responses of each alternative do vary, however, with the hydrologic loading. For simplicity, the system responses of the alternatives due to seismic and static loadings are discussed first, followed by the system responses due to the hydrologic loading for each alternative.

A. System Response and Associated Probabilities Due to Seismic Loadings

The following categories of dam failure modes due to seismic loadings were evaluated:

1. Landslide into the Reservoir (Reservoir Landslide).
2. Foundation Liquefaction.
3. Embankment Deformation.
4. Core Cracking and Piping through Core.
5. Rupture of the Outlet Works.

The system response and the associated probabilities for all alternatives due to seismic loadings are presented in Table VII-1.

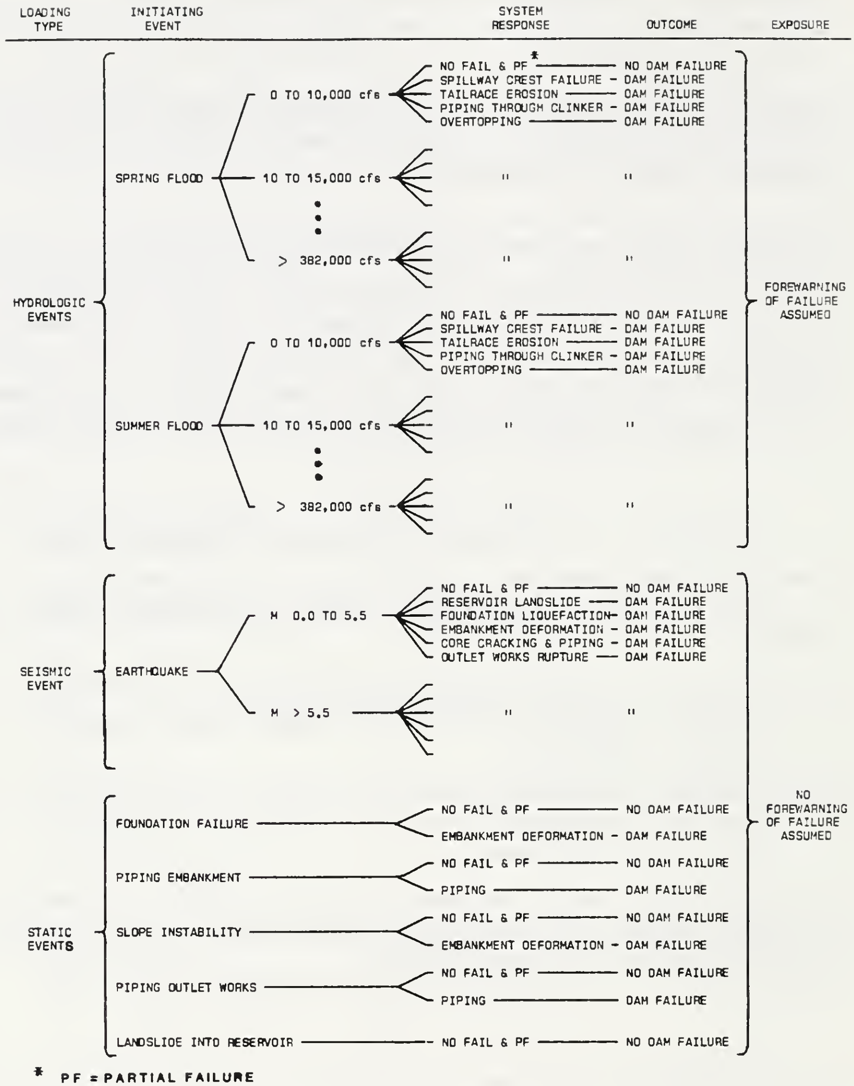


FIGURE VII-1 EVENT TREE

TABLE VII-1

System Response Probabilities Due to Seismic Events

Loading Event Type	System Response Type	System Response Probability
M 0 - 5.5	No Failure and Partial Failure	1.0
	Reservoir Landslide	0
	Embankment Deformation	0
	Core Cracking and Piping	0
	Outlet Rupture	0
> M 5.5	No Failure and Partial Failure	0.998
	Reservoir Landslide	.001
	Embankment Deformation	.001
	Core Cracking and Piping	0
	Outlet Rupture	0

B. System Response and Associated Probabilities Due to Static Loading

The conditional system response, due to static loadings, can be estimated in the following manner. Static loading on a dam is due to the hydrostatic pressure of the reservoir. The magnitude of this load varies with reservoir stage which is determined by the relationship between reservoir inflow and outflow. The Tongue River reservoir follows an annual cycle of high stages in the spring and lower stages in the fall and winter. Dams have been known to fail under static loading conditions independently of the occurrence of floods or earthquakes. Such failures can typically be attributed to either a design or latent construction defect or to a deterioration in the properties of materials in the structure. Examples of static failure modes include piping through the embankment and slope failure. Where evidence exists which indicates that a particular dam may be endangered by a static failure mode then this failure mode should be explicitly included in the risk model. Also, its system response and outcome probabilities should be assessed by experienced dam engineers using the results of investigations at the dam and subse-

quent analyses. Finally, appropriate remedial action should be taken. However, at the Tongue River Dam, no evidence of potential static failure modes is known to exist. In this situation, the likelihood of static failure of the Tongue River Dam is probably very small and can be estimated using the historical frequencies of static failures of similar dams.

The historical frequency method of dealing with static failure modes was proposed by Bowles et al. (1978) and subsequently pursued by the Bureau of Reclamation (Application of Statistical Data from Dam Failures and Accidents to Risk Based Decision Analysis on Existing Dams, USBR Internal Report, in press). The Bureau assembled an extensive data base of U.S. dams and their failures. This data base was added to by Stanford University (1985) under funding from the Federal Emergency Management Agency (FEMA), and has been most recently expanded by Hatem (1985) in a thesis written at Stanford University. All three studies have used the following categories for static failure modes of embankment dams:

1. Foundation failure.

2. Failure due to piping of the embankment not associated with the outlet works.

3. Embankment deformation failure.

4. Failure due to piping associated with the outlet works.

For this study, the historical frequencies of these four static failure modes were assessed using the three data bases referred to above. The procedures followed, using the three data bases and the estimates obtained for the Tongue River Dam, are summarized and compared in the following paragraphs.

The FEMA data base was assembled by Stanford University (1985). By sorting the data on dam failures by type of dam and type of failure mode and by considering the age of the dams, a historical frequency of failure for each failure mode,

expressed on a per year basis, was obtained. These frequencies can be interpreted as an estimate of the probability of failure due to a particular failure mode of a dam which appears to be in "average" condition with respect to observable factors that would be associated with that failure mode. In an attempt to adjust these probability estimates to be representative of dams which appear to be better or worse than "average," the Stanford researchers developed a subjective 10-point evaluation scale. The scale is based on information that typically would be available in a Corps of Engineers Phase I Inspection Report. If a particular dam is rated "poorer than average" on the evaluation scale, then a higher probability of failure is assigned and, conversely, if the dam is rated "better than average," then a lower probability of failure is assigned. Using the evaluation scales in the Stanford (1985) report for the four static failure modes, the Tongue River Dam was rated by the following:

1. PRC staff and consultants.
2. DNRC project staff.
3. Richard Harlan, Consulting Engineer to DNRC for Tongue River Dam.

The PRC team was comprised of four engineers with a variety of engineering backgrounds. Each team member independently evaluated the Tongue River Dam and the basis for their evaluations was discussed until a consensus was reached on the rating to be given by the group. Next, the DNRC project staff, comprised of three engineers with between three (3) and sixteen (16) years experience with the Tongue River Dam independently evaluated the dam. These evaluations were discussed with the DNRC project staff until a consensus of the combined group was reached. Finally, Mr. Harlan, who has served as a consulting engineer to DNRC for the Tongue River Dam for approximately 20 years, independently evaluated the dam. His evaluation was then discussed by the combination of all three groups until an overall consensus was reached on the rating for the four static failure modes. Using these ratings, the estimates of the probability of failure for each static failure mode were obtained from the FEMA report (Stanford 1985). Throughout the iterative process, changes in ratings were justified based on engineering considerations.

The second method of estimating the probabilities of static failure of the Tongue River Dam utilized Hatem's recently completed thesis (Hatem 1985). Hatem expanded the FEMA data base and categorized the dams by type, age, and type of failure mode to determine a historical frequency of failure for each failure mode, expressed on a per year basis. As with the FEMA study, these frequencies can be viewed as applying to a dam which appears to be in "average" condition considering observable factors that would be associated with the failure mode under consideration. In an attempt to adjust these frequencies to represent cases of dams which appear to be better or poorer than "average," Hatem used statistical methods to calculate 10% and 90% confidence limits on the probability estimates, corresponding to dams in "better than average" or "poorer than average" condition, respectively. However, Hatem did not relate the 10%, 50% (average), or 90% probabilities to specific descriptions of the condition of the dam. Therefore, the user is left with three choices of "better than average" (10%), "average" (50%), and "poorer than average" (90%). For the Tongue River Dam, it was the consensus of the consultant team and the DNRC project staff that the Tongue River Dam should be evaluated as "better than average" for static loading, except for the foundation failure mode which was considered to be between "better than average" and "average." The estimated probabilities of failure for each failure mode were obtained from Hatem (1985) corresponding to the 10% (or 50%) probability estimates for an earth dam greater than five years old.

The third method of estimating the static failure probability is that used by the Bureau of Reclamation (Applications of Statistical Data from Dam Failures and Accidents to Risk Based Decision Analysis on Existing Dams, USBR, Internal Report, in press). This method uses a three-step process to determine the probability of static failure due to all causes. The first step is to look at a historical rate of failure as compiled by the Bureau of Reclamation. A minimum and maximum rate of failure is determined to represent the range of interpretations that can be made from the historical dam failure data and to account for the uncertainties. The second step looks at the site specific conditions of the dam and the third step determines a failure rate based on the results of the second step and the historical failure information.

The historical data for a dam that falls in the category of earth dams built after 1930 but prior to 1960, in the western United States, 50 to 100 feet high, shows two static failures with 8,200 dam years of operation. This gives a probability of 2.44×10^{-4} per dam year. For dams in the same category but in the eastern United States, the rate is three failures in 15,064 dam years of operation for 2.0×10^{-4} per dam year with a weighted average for number of dam years of 2.2×10^{-4}. Examining all dams built between 1930 and 1960, the probabilities are 3.8×10^{-5} for western dams and 2.2×10^{-5} for eastern dams. Examining all dams in the height category, the probability ranges from a high of 1.5×10^{-3} to a low of 4.3×10^{-4}. An aggregate of all failures shows that the failure rate for dams greater than 50 feet high in the western United States built after 1930 is 4×10^{-4}. If 20% of failures for all dams over 50 feet high are due to overtopping and spillway failures and 80% are static failures, the average static failure rate is 3.2×10^{-4} which falls within the range of averages as discussed above.

The "average" dam in this category then has an estimated range of probability of static failure of 3.8×10^{-5} to 6.1×10^{-4}, and the weighted average for the specific type of dams is 2.2×10^{-4} per dam year. However, for static failures 75% of all failures occur in the first ten years of operation. Since this dam is older than ten years, the probability can be reduced by about 75% to an estimated range from 9.4×10^{-6}, to 1.5×10^{-4} and a weighted average of 5.4×10^{-5}.

The second step of looking at this specific dam showed no reason to suppose that this dam is any better or worse than any other dam. Therefore, in the third step using engineering judgement, it was appropriate to use a total static failure rate equal to 5.4×10^{-5}.

The results of all three methods are given in Table VII-2. All three methods gave quite similar results which gave a bias for confidence in the results.

TABLE VII-2

Static Loading

Conditional System Response Probabilities

	Static Failure Mode	FEMA	Hatem	USBR	Historical
1.	Foundation Failure	3.6×10^{-5}	1.3×10^{-5}	N/A	
2.	Piping of the Embankment	1.2×10^{-5}	4.2×10^{-5}	N/A	
3.	Slope Instability	2.8×10^{-6}	1.5×10^{-6}	N/A	
4.	Piping Around the Outlet Works	1.6×10^{-6}	4.4×10^{-6}	N/A	
		5.2×10^{-5}	6.1×10^{-5}	5.4×10^{-5}	
5.	Landslide Into Reservoir				1.0×10^{-3}

The FEMA values were used for the static failure mode probabilities. In the case of the Tongue River Dam, the probability of occurrence of a landslide into the reservoir was estimated to be 0.001 per year based on the historical record of landslides in the Tongue River reservoir.

C. System Responses and Associated Probabilities Due to Hydrologic Loading

Under each hydrologic loading condition, the following categories of dam failure modes (system response type) were evaluated (see event tree Figure VII-1):

1. Spillway crest failure.
2. Erosion of spillway tailrace channel.
3. Piping through clinker.
4. Overtopping of embankment.

The conditional response probability for each failure mode corresponding to each loading condition was estimated for each alternative. The estimations were made after a site visit and discussion sessions among the PRC team members, the DNRC project staff, and Mr. Harlan. Experiences from the 1978 flood, the 1982 safety inspection of the dam, and operation and maintenance history of the project were also drawn upon in estimating response probability for each failure mode.

Alternative A - Existing dam with no structural modifications and present reservoir operating restrictions removed - "Existing Dam"

This alternative consists of providing no structural modification to Tongue River Dam. It is described in the Basic Design Report Supporting Data, State of Montana, Water Resource Board, Tongue River Project, Bechtel Corporation, SF 1969; Geologic and Materials Report, Tongue River Dam and Alternate Damsites, Big Horn and Rosebud Counties Montana, May 1982, USBR Upper Missouri Regional Office; Planning Report and Preliminary Environmental Review Appendix B, USBR for Montana Department of Natural Resources and Conservation, Tongue River Dam Study, March 1985. The risk associated with it is the current level of risk people are living with. This alternative restores full project benefits by restoring full pool storage but no additional flood control storage or spillway capacity is provided. In fact, some flood control storage gained as a result of the current restrictions is lost when the current operating restrictions are removed. Consequently, populations downstream would likely have a reduced warning time and the decision to warn people and evacuate becomes increasingly critical in this alternative. The potential for dam failure increases because the existing spillway would operate in its present condition more frequently.

The system response due to the hydrological loadings is described in this paragraph. First, spillway discharges over 6,800 cfs were found in the 1978 flood to begin eroding the tailrace area. As the water head increases, the spillway crest is expected to begin to suffer damages and possibly begin breaking up with four to five feet of water going over the crest (HMT Associates). With more than 20,000 cfs between W.S. elevations 3428.4 and 3429.4, it is probable that the spillway crest could fail and erosion of the tailrace area could become significant. Failure of the spillway leads to a sudden increase in discharges from the reservoir. If the reservoir water surface continues to increase due to a major storm, the seepage problems would probably become more serious with the potential of leading to failure of the structure by piping through the clinker. It is the opinion of the consultant team, DNRC staff, and Mr. Harlan that the structure could fail due to some combination of spillway crest failure, tailrace erosion, or piping before overtopping would occur. The system response probabilities are shown in Table VII- 3.

TABLE VII-3
Tongue River Dam-Risk Analysis
Conditional Response Probabilities
Alternative A - Existing Dam
Event type: Spring Flood

Peak Inflow (1,000 cfs)	0-10	10-15	15-20	20-25	25-30	30-50	50-80	80-110	110-200	200-382	382
Peak Outflow (1,000 cfs)	0-7	7-11	11-16	17-20	20-24	24-42	42-68	68-103	103-196	196-379	379
System Response											
1. NF + (PF)*	1.00	0.95	0.85	0.65	0.45	0.15	0.00	0.00	0.00	0.00	0.00
2. Spillway Crest	0.00	0.00	0.05	0.20	0.30	0.40	0.45	0.45	0.45	0.45	0.45
3. Tailrace Erosion	0.00	0.05	0.10	0.15	0.25	0.40	0.45	0.45	0.45	0.45	0.45
4. Piping Clinker	0.00	0.00	0.00	0.00	0.00	0.05	0.10	0.10	0.10	0.10	0.10
5. Overtopping	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Event type: Summer Flood

Peak Inflow (1,000 cfs)	0-10	10-15	15-20	20-25	25-30	30-50	50-80	80-110	110-200	200-382	382
Peak Outflow (1,000 cfs)	0-7	7-11	11-16	17-20	20-24	24-42	42-68	68-103	103-196	196-379	379
System Response											
1. NF + (PF)*	1.00	0.97	0.90	0.75	0.55	0.20	0.00	0.00	0.00	0.00	0.00
2. Spillway Crest	0.00	0.00	0.03	0.16	0.28	0.38	0.45	0.45	0.45	0.45	0.45
3. Tailrace Erosion	0.00	0.03	0.07	0.09	0.17	0.38	0.45	0.45	0.45	0.45	0.45
4. Piping Clinker	0.00	0.00	0.00	0.00	0.00	0.04	0.10	0.10	0.10	0.10	0.10
5. Overtopping	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

*NF = No Failure; (PF) = Partial Failure

Alternative B - Modify the dam and spillway to safely pass the PMF and increase reservoir storage - "Spillway Capacity 382,000 cfs (100% PMF)."

This alternative is described in Planning Report and Preliminary Environmental Review, USBR for MDNR & C, Tongue River Dam Study, March, 1985; Tongue River Dam Modification, Feasibility Design Data, MDNR & C, Tongue River Project, August 29, 1984; Draft DNRC 1985 Summary Report (Alternative 1a) and involves modifications to the dam and spillway to safely pass the PMF of 382,000 cfs. The spillway crest would be rebuilt and founded on sandstone and siltstone. Seepage control would be provided by a cutoff trench connecting the existing dam cutoff trench to the spillway cutoff trench and extending the trench through the clinker to the west along the shore of the reservoir. The crest of the uncontrolled spillway would be raised to elevation 3428.4 providing an additional

four feet of storage. The spillway would be widened to 500 feet so that it would pass 96,000 cfs at a reservoir water surface level of elevation 3442. A new stilling basin would be built to replace the old hydraulically inefficient basin. The crest of the dam would be raised to elevation 3465.0 which would provide 3.5 feet of freeboard under PMF conditions. The new embankment would be constructed on the site of the existing berms (which would be removed) immediately downstream of the existing dam. The foundation area would be densified using deep dynamic compaction. The crest would be raised and moved downstream of the existing dam. The new crest would be 40 feet wide with 3:1 upstream slope and with 2:1 and 1½:1 downstream slopes. The existing dam would be used in part for the upstream shell of the new dam.

The structure would not be expected to fail when operated up to the full PMF. Some uncertainty may remain because of the possibility of failure by piping through the clinker due to known foundation problems which may or may not be entirely resolved during construction of the new structure.

The system response due to increasing inflow floods would be expected to follow the sequence of events described in this paragraph. The improvements to the dam, foundation, and spillway would be expected to improve the conditions to prevent failure of the dam up to spillway discharges of 200,000 cfs at elevation 3452.0. Because of the poor foundation conditions it is judged unrealistic to expect to completely solve the seepage problems. Hence, some slight risk would remain of the dam failing due to piping through the clinker. Should the PMF inflow be exceeded, there is 3.5 feet of freeboard available before overtopping would occur. The conditional response probability of dam failure for inflows greater than the PMF was estimated to be about 15%. The estimated probabilities of the system response described above are shown in Table VII-4.

TABLE VII-4

Tongue River Dam-Risk Analysis
Conditional System Response
Alternative B - Spillway Capacity 382,000 (100% PMF)

Event Type: Spring Flood

Peak Inflow (1,000 cfs)	0-10	10-15	15-20	20-25	25-30	30-50	50-80	80-110	110-200	200-382	382
Peak Outflow (1,000 cfs)	0-7	7-11	11-16	17-20	20-24	24-42	42-68	68-103	103-196	196-379	379
System Response											
1. NF + (PF)*	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.95	0.85
2. Spillway Crest	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3. Tailrace Erosion	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4. Piping Clinker	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05
5. Overtopping	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10

Event Type: Summer Flood

Peak Inflow (1,000 cfs)	0-10	10-15	15-20	20-25	25-30	30-50	50-80	80-110	110-200	200-382	382
Peak Outflow (1,000 cfs)	0-7	7-11	11-16	17-20	20-24	24-42	42-68	68-103	103-196	196-379	379
System Response											
1. NF + (PF)*	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.95	0.85
2. Spillway Crest	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3. Tailrace Erosion	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4. Piping Clinker	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05
5. Overtopping	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10

*NF = No Failure; (PF) = Partial Failure

Alternative C - Modify the dam and spillway to pass a 103,400 cfs flood - "Spillway Capacity 103,400 cfs (27% PMF)."

This alternative has been identified and described in Engineering Feasibility Study, Tongue River Spillway Modification, Harlan Miller Tait Associates, June 4, 1985 as a "patchwork" alternative and also as Alternative No. 2a in the draft DNRC 1985 Summary Report. It involves modifying the spillway to safely pass 103,400 cfs at a reservoir water surface of elevation 3442.4. The spillway crest would be rebuilt and founded on sandstone and siltstone. The spillway crest elevation and width, 3424.4 and 350 feet respectively, would remain the same as the existing structure. The spillway chute would be stabilized by rock anchors. The stilling basin would be rebuilt and widened to 250 feet from the present 100 feet. A new slurry trench would be constructed under the spillway crest to control seepage. The slurry trench would connect to the dam cutoff trench, cross the spillway approach channel, and extend to the west upstream of the left abutment to control seepage

through the clinker. Grouting would be provided under the spillway chute. The embankment crest would be raised 10 feet through a dumped waste method to elevation 3452.0 and foundation improvements would be provided.

The purpose of this alternative would be to provide protection up to approximately 103,400 cfs outflow before potential overtopping occurs. The dumped waste method of raising the crest of the embankment provides some protection against overtopping. If an engineered fill were used for raising the embankment crest, the spillway would possibly discharge approximately 200,000 cfs with the reservoir water surface at elevation 3452. Some potential will exist for piping through the clinker due to the existing foundation conditions, given the known seepage problems and the difficulty experienced in correcting the problems. The estimated system response probabilities are shown in Table VII-5.

TABLE VII-5
Tongue River Dam-Risk Analysis
Conditional System Response
Alternative C - Spillway Capacity 103,400 (24% PMF)

Event Type: Spring Flood

Peak Inflow (1,000 cfs)	0-10	10-15	15-20	20-25	25-30	30-50	50-80	80-110	110-200	200-382	382
Peak Outflow (1,000 cfs)	0-7	7-11	11-16	17-20	20-24	24-42	42-68	68-103	103-196	196-379	379
System Response											
1. NF & (PF)*	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.95	0.50	0.05	0.00
2. Spillway Crest	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3. Tailrace Erosion	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4. Piping Clinker	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.10	0.10	0.15
5. Overtopping	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.85	0.85

Event Type: Summer Flood

Peak Inflow (1,000 cfs)	0-10	10-15	15-20	20-25	25-30	30-50	50-80	80-110	110-200	200-382	382
Peak Outflow (1,000 cfs)	0-7	7-11	11-16	17-20	20-24	24-42	42-68	68-103	103-196	196-379	379
System Response											
1. NF & (PF)*	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.95	0.50	0.05	0.00
2. Spillway Crest	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3. Tailrace Erosion	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4. Piping Clinker	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.10	0.10	0.15
5. Overtopping	0.00	0.00	0.00	0..00	0.00	0.00	0.00	0.00	0.40	0.85	0.85

*NF = No Failure; (PF) = Partial Failure

Alternative D - Modify the spillway and energy dissipator to pass a design capacity of 60,000 cfs (the original intended design capacity at a water surface of elevation 3437.4 based on original construction drawing No. 9-GR dated March 14, 1938) - "Spillway Capacity 60,000 cfs (16% PMF)."

This alternative described in Engineering Feasibility Study, Tongue River Spillway Modification, Harlan Miller Tait Associates, June 4, 1985 and in the draft DNRC 1985 Summary Report (Alternative 2b) involves work on the spillway to reduce the likelihood of failure of the spillway. It would rehabilitate the dam, spillway, and energy dissipator to pass the originally intended design capacity of 60,000 cfs. Limited work would be performed on the spillway chute, but the spillway crest and the energy dissipator would be replaced. Some work would be included to reduce the potential of piping through the abutments. No work would be done on the embankment and the dam crest would remain at elevation 3442.4. The estimated system response probabilities for this alternative are shown in Table VII-6.

TABLE VII-6
Tongue River Dam-Risk Analysis
Conditional System Response
Alternative D - Spillway Capacity 60,000 (16% PMF)

Event Type: Spring Flood

Peak Inflow (1,000 cfs)	0-10	10-15	15-20	20-25	25-30	30-50	50-80	80-110	110-200	200-382	382
Peak Outflow (1,000 cfs)	0-7	7-11	11-16	17-20	20-24	24-42	42-68	68-103	103-196	196-379	379
System Response											
1. NF & (PF)*	1.00	1.00	1.00	1.00	1.00	1.00	0.90	0.75	0.20	0.00	0.00
2. Spillway Crest	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.10	0.15	0.15	0.15
3. Tailrace Erosion	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.10	0.15	0.15	0.15
4. Piping Clinker	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.10	0.10	0.10
5. Overtopping	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.60	0.60

Event Type: Summer Flood

Peak Inflow (1,000 cfs)	0-10	10-15	15-20	20-25	25-30	30-50	50-80	80-110	110-200	200-382	382
Peak Outflow (1,000 cfs)	0-7	7-11	11-16	17-20	20-24	24-42	42-68	68-103	103-196	196-379	379
System Response											
1. NF & (PF)*	1.00	1.00	1.00	1.00	1.00	1.00	0.90	0.75	0.20	0.00	0.00
2. Spillway Crest	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.10	0.15	0.15	0.15
3. Tailrace Erosion	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.10	0.15	0.15	0.15
4. Piping Clinker	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.10	0.10	0.10
5. Overtopping	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.60	0.60

*NF = No Failure; (PF) = Partial Failure

Alternative E - Breaching the dam and restoration of the reservoir area -"Breach"

This alternative is referenced in the draft DNRC 1986 Summary Report. It is presented as a preliminary alternative and its associated costs. The cost of breaching the dam and restoration of the reservoir area was computed by Harlan Miller Tait Associates, while the construction cost of this alternative was taken from the draft 1985 Summary Report (Alternative 3b). The alternative involves breaching the dam and restoring the reservoir area. This alternative eliminates all risk due to dam failure; however, all benefits from the dam (recreation, water supply, incidental flood control) would be lost. It should be remembered that the downstream areas would still be vulnerable to flood damage due to natural flood flows should storms move into the area. There are no system response probabilities (hydrologic, seismic, or static) for this alternative because there is no dam.

VIII. CONSEQUENCE ASSESSMENT

A. Introduction

Two types of consequences were considered in this study which are associated with the risk of structural failure of the Tongue River Dam and the release of its reservoir contents. One involves primarily economic consequences such as property damage, loss of personal and business income, interruption of public services, and loss of project benefits. The other is the potential threat to life which risk of dam failure poses. The following assessment provides a characterization of these two major consequences for the Tongue River Dam and the Tongue River region and provides estimates of the economic damages and the potential threat to life. It also documents the dam break and flood routing studies which were performed to delineate the estimated extent of the flood plain associated with various failure and non-failure scenarios.

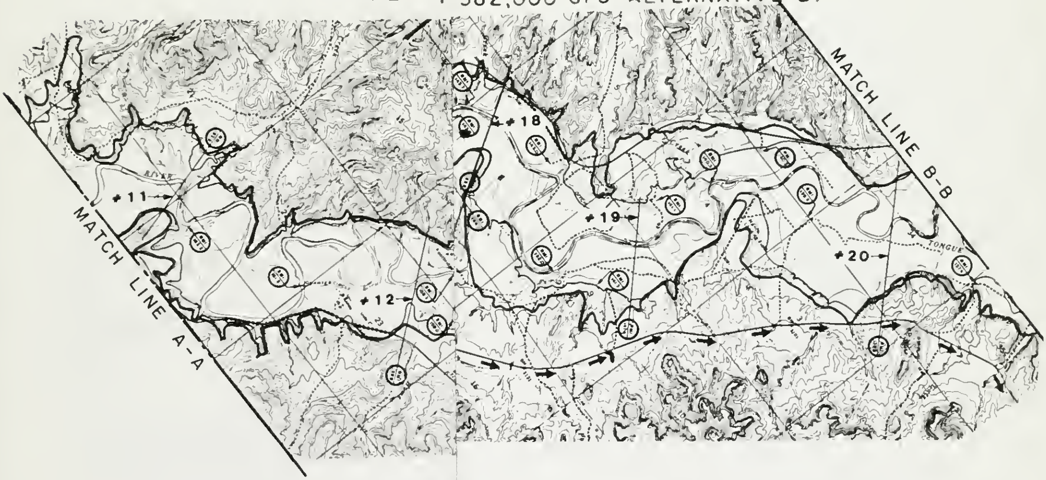
B. Inundation Studies

General

The determination of flood inundation areas downstream of Tongue River Dam, due to floods resulting from various dam failure and non-failure scenarios, is essential in assessing property damage and potential life loss. The assessment of damages was made by evaluating the flood areas associated with each loading condition. For each of the rehabilitation alternatives studied in this report, breach outflows associated with each loading condition were determined. Breach outflows were routed down the Tongue River from Tongue River Dam to Miles City. The total river mileage between Tongue River Dam to Miles City is 187. Figure VIII-1 (Sheets 1 through 4) shows plans of the Tongue River and the designation of channel sections used in the flood routing calculations.

TONGUE RIVER DAM

DAM B- SPRING FLOOD EVENT
PLAN, 382,000 CFS ALTERNATIVE B.



CTION #18
RNEY DAY SCHOOL

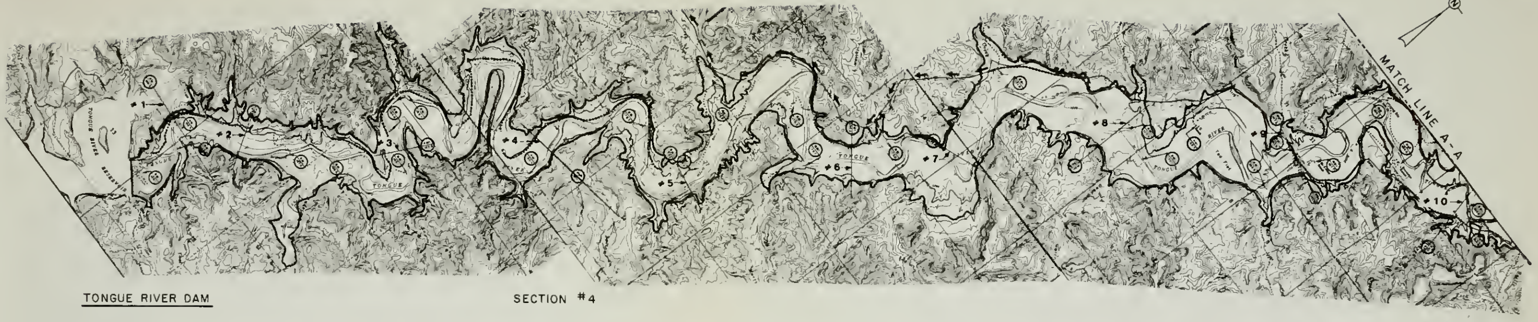
LEGEND.

- FLOOD BOUNDARY-SPRING FLOOD EV
- DAM BREACH FLOOD BOUNOARY ONRC EV
- RMI 113 — RIVER MILE INDEX / RIVER MILEAGE ABOVE MOUTH
- RMI — FLOOD ROUTING CROSS SECTION
- FLOODED ROAD SECTIONS
- EVACUATION ROUTES TO EMERGENCY SERVIC
- G—G— GAS LINE — BURIED GAS LINE CROSSING
- RMI — POWER LINE — OVERHEAD POWER LINE CROSSING
- T—T— TELE CABLE — BURIED TELEPHONE CABLE CRO

TONGUE RIVER DAM
RISK ASSESSMENT

FIGURE VIII-1 FLOOD BOUNDARIES AND PLAN AND CROSS SECTION DESIGNATIONS OF TONGUE RIVER

SHEET 1 OF 4



TONGUE RIVER DAM

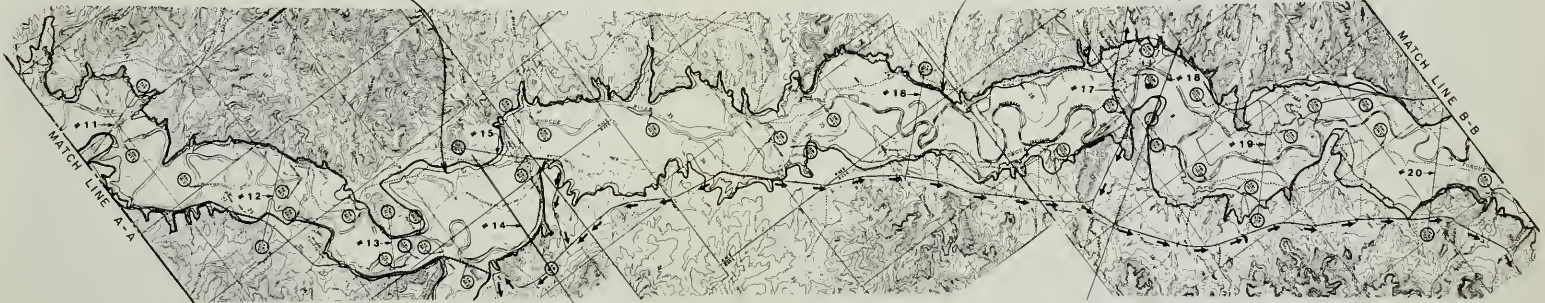
SECTION #4

PLAN

RIVER MILE 164-189.1

DAM BREACH FLOOD BOUNDARY DNRC EVALUATION PLAN, JULY 1982

FLOOD BOUNDARY - SPRING FLOOD EVENT PEAK DISCHARGE 382,000 CFS ALTERNATIVE 8.



SECTION #14
NEAR BIRNEY

SECTION #18
BIRNEY DAY SCHOOL

LEGEND.

- FLOOD BOUNDARY - SPRING FLOOD EVENT PEAK DISCHARGE 382,000 CFS ALTERNATIVE 8
- DAM BREACH FLOOD BOUNDARY DNRC EVACUATION PLAN, JULY 1982
- RMI 113 — RIVER MILE INDEX, RIVER MILEAGE ABOVE MOUTH
- RM — FLOOD ROUTING CROSS SECTION
- FLOODED ROAD SECTIONS
- EVACUATION ROUTES TO EMERGENCY SERVICE FACILITIES
- G GAS LINE — BURIED GAS LINE CROSSING
- POWER LINE — OVERHEAD POWER LINE CROSSING
- T TELE CABLE — BURIED TELEPHONE CABLE CROSSING

PLAN

RIVER MILE 137.5-164

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SCALE OF MILE

TONGUE RIVER DAM
RISK ASSESSMENT

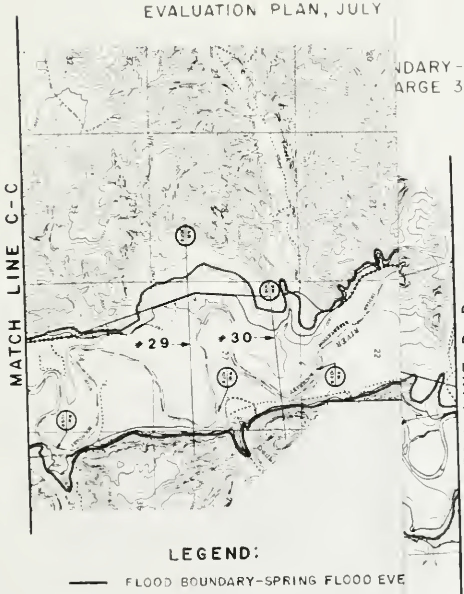
FIGURE VIII-1 FLOOD BOUNDARIES AND PLAN AND CROSS SECTION DESIGNATIONS OF TONGUE RIVER

SHEET 1 OF 4

SECTION #28
ASHLAND

DAM BREACH FLOOD BOU
EVALUATION PLAN, JULY

NDARY-SPRING FLOOD EVENT
ARGE 382,000 CFS ALTERNATIVE B



LEGEND:

- FLOOD BOUNDARY-SPRING FLOOD EVE
- DAM BREACH FLOOD BOUNDARY DNRC EVA
- RM 11.3 — RIVER MILE INDEX / RIVER MILEAGE ABOVE MOUTH
- RM1 — FLOOD ROUTING CROSS SECTION
- .... FLOODED ROAD SECTIONS
- → EVACUATION ROUTES TO EMERGENCY SERVICI
- G—G— GAS LINE — BURIED GAS LINE CROSSING
- SMI POWER LINE — OVERHEAD POWER LINE CROSSING
- T—T— TELE CABLE — BURIED TELEPHONE CABLE CRO

TONGUE RIVER DAM
RISK ASSESSMENT

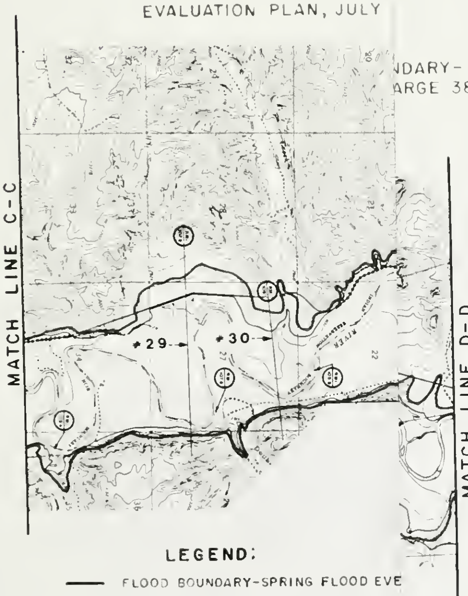
FIGURE VIII-1 FLOOD BOUNDARIES AND PLAN AND CROSS SECTION DESIGNATIONS OF TONGUE RIVER

SHEET 2 OF 4

SECTION #28
ASHLAND

DAM BREACH FLOOD BOU
EVALUATION PLAN, JULY

NDARY-SPRING FLOOD EVENT
ARGE 382,000 CFS ALTERNATIVE B



LEGEND:

- FLOOD BOUNDARY-SPRING FLOOD EVE
- DAM BREACH FLOOD BOUNDARY DNRC EVA
- RMI 113 RIVER MILE INDEX / RIVER MILEAGE ABOVE MOUTH
- RMI FLOOD ROUTING CROSS SECTION
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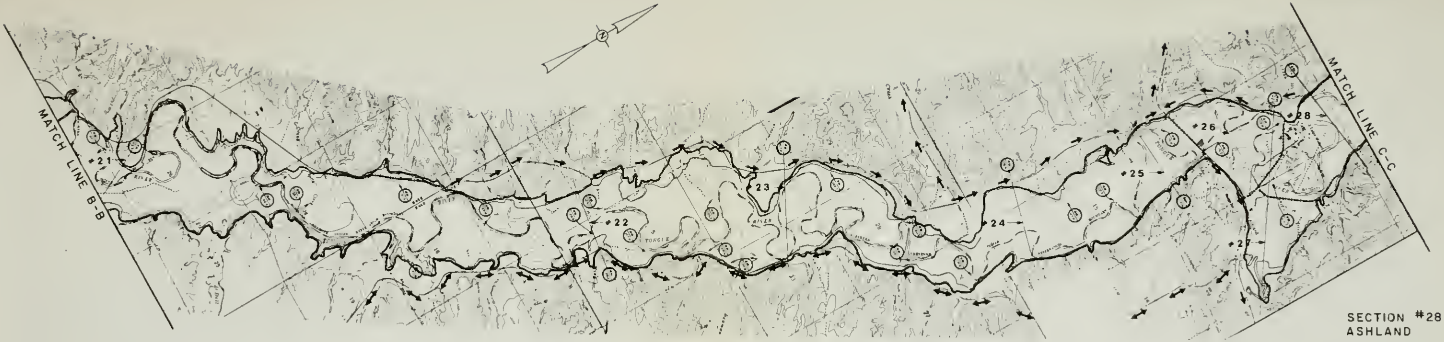
- EVACUATION ROUTES TO EMERGENCY SERVICI
- G—G— GAS LINE BURIED GAS LINE CROSSING
- RMI POWER LINE OVERHEAD POWER LINE CROSSING
- T—T— TELE CABLE BURIED TELEPHONE CABLE CRO

TONGUE RIVER DAM
RISK ASSESSMENT

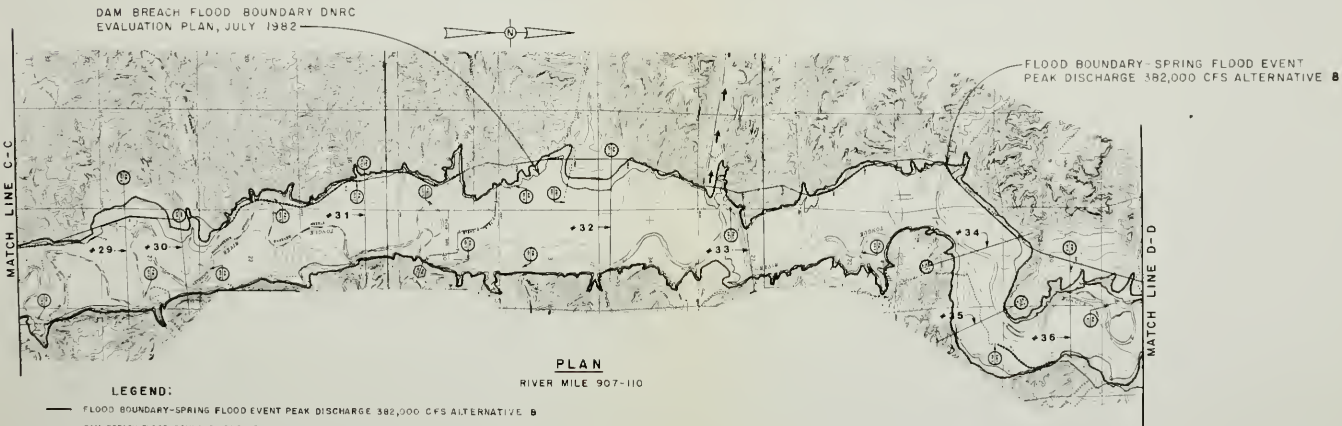
FIGURE VIII-1 FLOOD BOUNDARIES AND PLAN AND CROSS SECTION DESIGNATIONS OF TONGUE RIVER

SHEET 2 OF 4



PLAN

RIVER MILE 110-1375



PLAN

RIVER MILE 907-110

LEGEND:

- FLOOD BOUNDARY-SPRING FLOOD EVENT PEAK DISCHARGE 382,000 CFS ALTERNATIVE B
- DAM BREACH FLOOD BOUNDARY DNRC EVACUATION PLAN, JULY 1982
- RIVER MILE INDEX RIVER MILEAGE ABOVE MOUTH
- FLOOD ROUTING CROSS SECTION
- FLOODED ROAD SECTIONS
- EVACUATION ROUTES TO EMERGENCY SERVICE FACILITIES
- GAS LINE — BURIED GAS LINE CROSSING
- POWER LINE — OVERHEAD POWER LINE CROSSING
- TELE CABLE — BURIED TELEPHONE CABLE CROSSING

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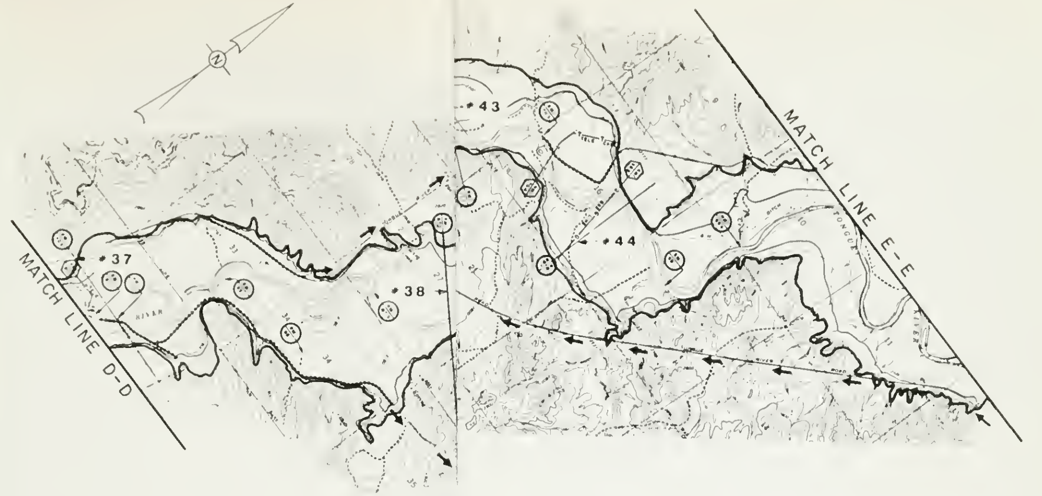
SCALE OF MILE

TONGUE RIVER DAM
RISK ASSESSMENT

FIGURE VIII-1 FLOOD BOUNDARIES AND PLAN AND CROSS SECTION DESIGNATIONS OF TONGUE RIVER

SHEET 2 OF 4



USGS GA

NT PEAK DISCHARGE 382,000 CFS ALTERNATIVE B

JATION PLAN, JULY 1982

FACILITIES

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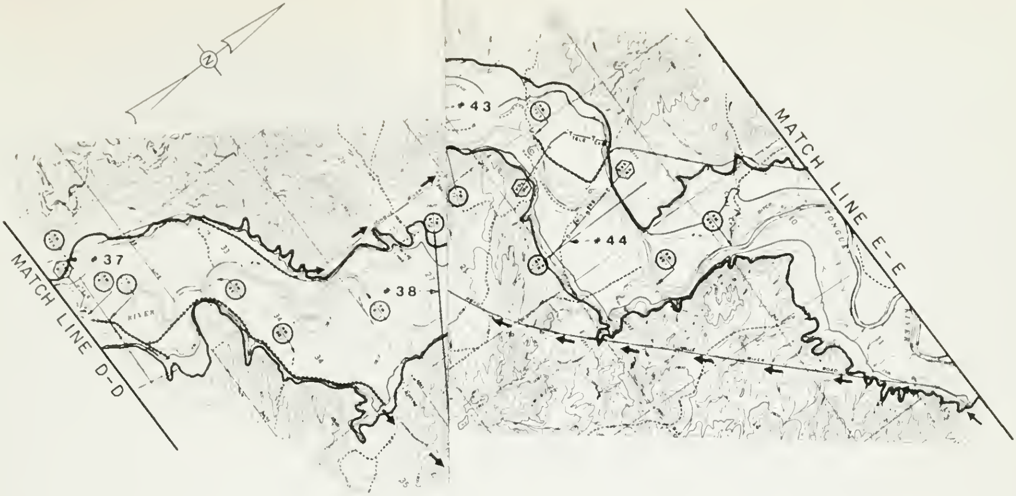
TONGUE RIVER DAM

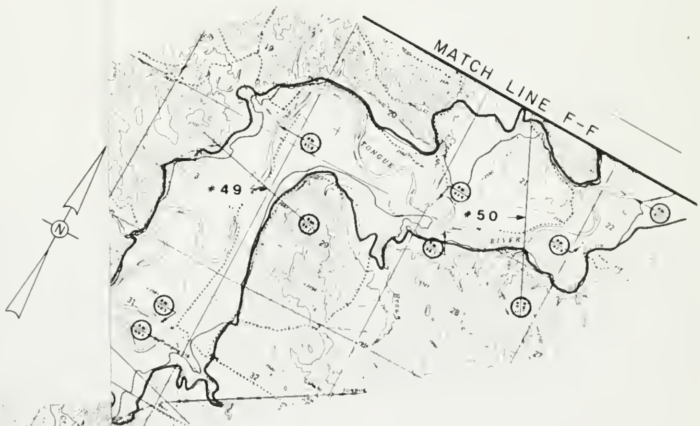
RISK ASSESSMENT

FIGURE VIII-1 FLOOD BOUNDARIES AND PLAN AND CROSS SECTION DESIGNATIONS OF TONGUE RIVER

SHEET 3 OF 4



USGS G/



NT PEAK DISCHARGE 382,000 CFS ALTERNATIVE B

JATION PLAN, JULY 1982

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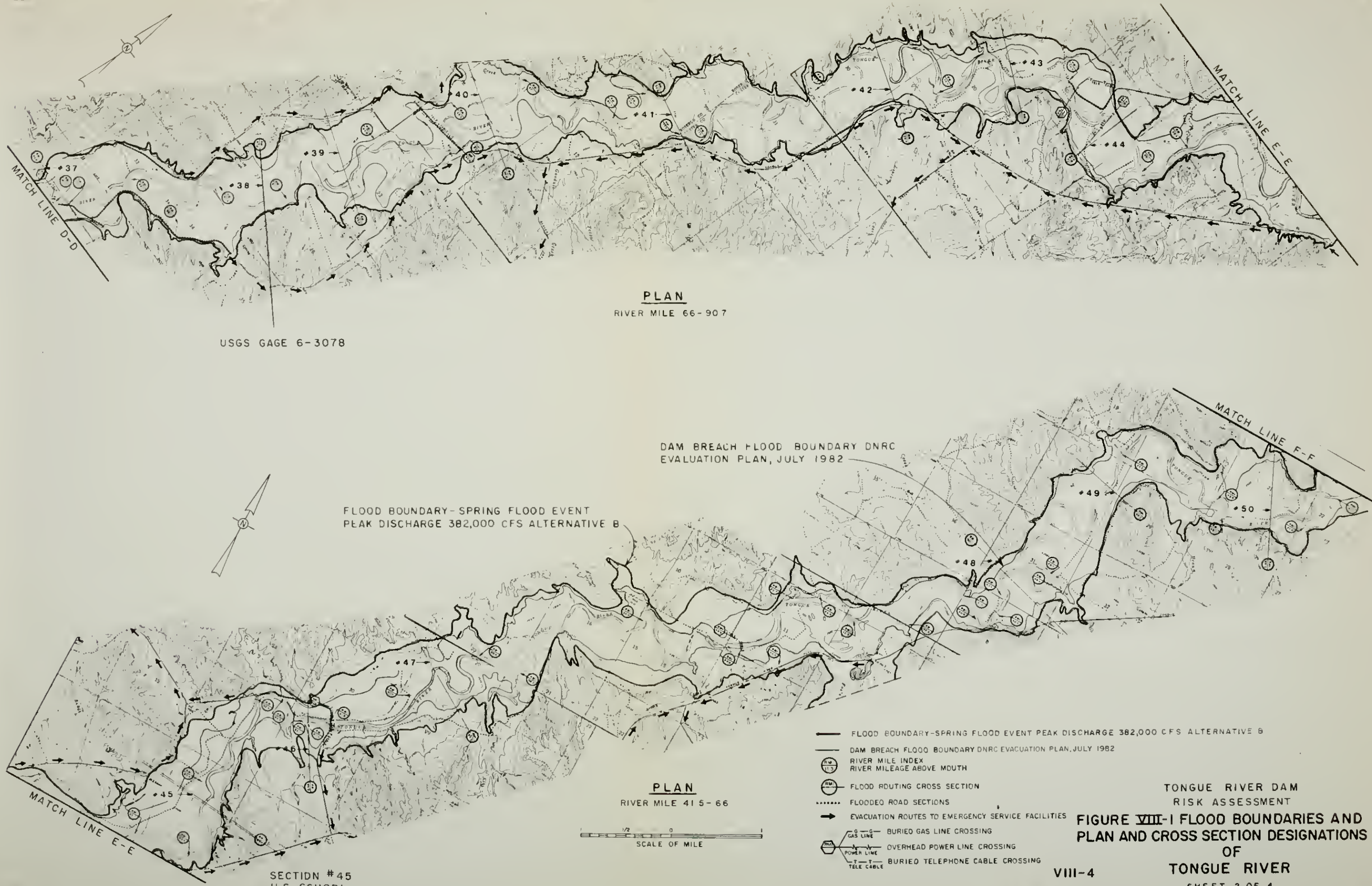
TONGUE RIVER DAM

RISK ASSESSMENT

FIGURE VIII-1 FLOOD BOUNDARIES AND PLAN AND CROSS SECTION DESIGNATIONS OF TONGUE RIVER

SHEET 3 OF 4



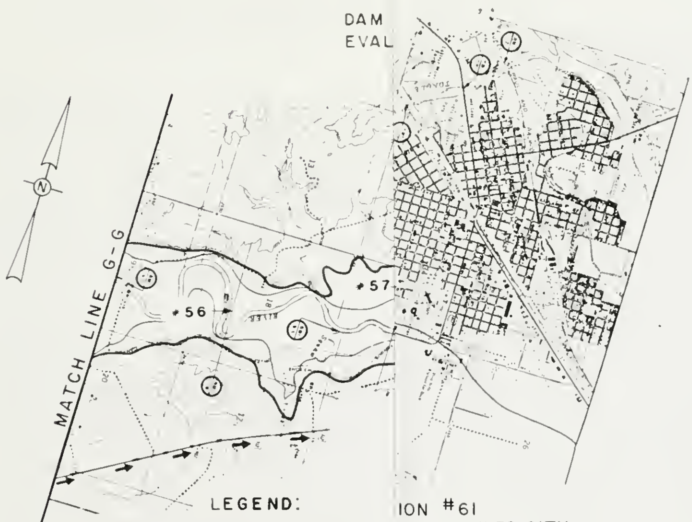
TONGUE RIVER DAM
RISK ASSESSMENT

FIGURE VIII-1 FLOOD BOUNDARIES AND PLAN AND CROSS SECTION DESIGNATIONS OF TONGUE RIVER

SHEET 3 OF 4

-SPRING FLOOD EVENT
382,000 CFS ALTERNATIVE B

DAM
EVAL



ION #61
NEAR MILES CITY

LEGEND:

- FLOOD BOUNDARY-SPRING FLO
- DAM BREACH FLOOD BOUNDARY ON
- RIVER MILE INDEX RIVER MILEAGE ABOVE MOUTH
- FLOOD ROUTING CROSS SECTION
- FLOODED ROAD SECTIONS
- EVACUATION ROUTES TO EMERGENCY
- GAS LINE BURIED GAS LINE CROSSING
- POWER LINE OVERHEAD POWER LINE CR
- TELE CABLE BURIED TELEPHONE CAB

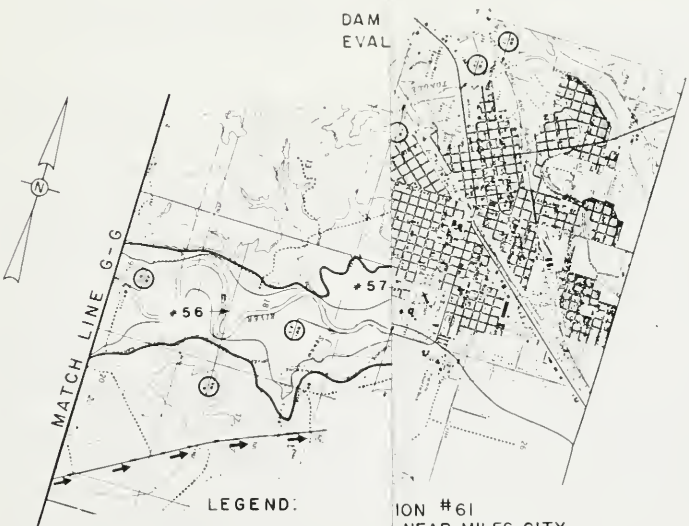
TONGUE RIVER DAM
RISK ASSESSMENT

FIGURE VIII-1 FLOOD BOUNDARIES AND PLAN AND CROSS SECTION DESIGNATIONS OF TONGUE RIVER

SHEET 4 OF 4

-SPRING FLOOD EVENT
382,000 CFS ALTERNATIVE B

DAM
EVAL



LEGEND:

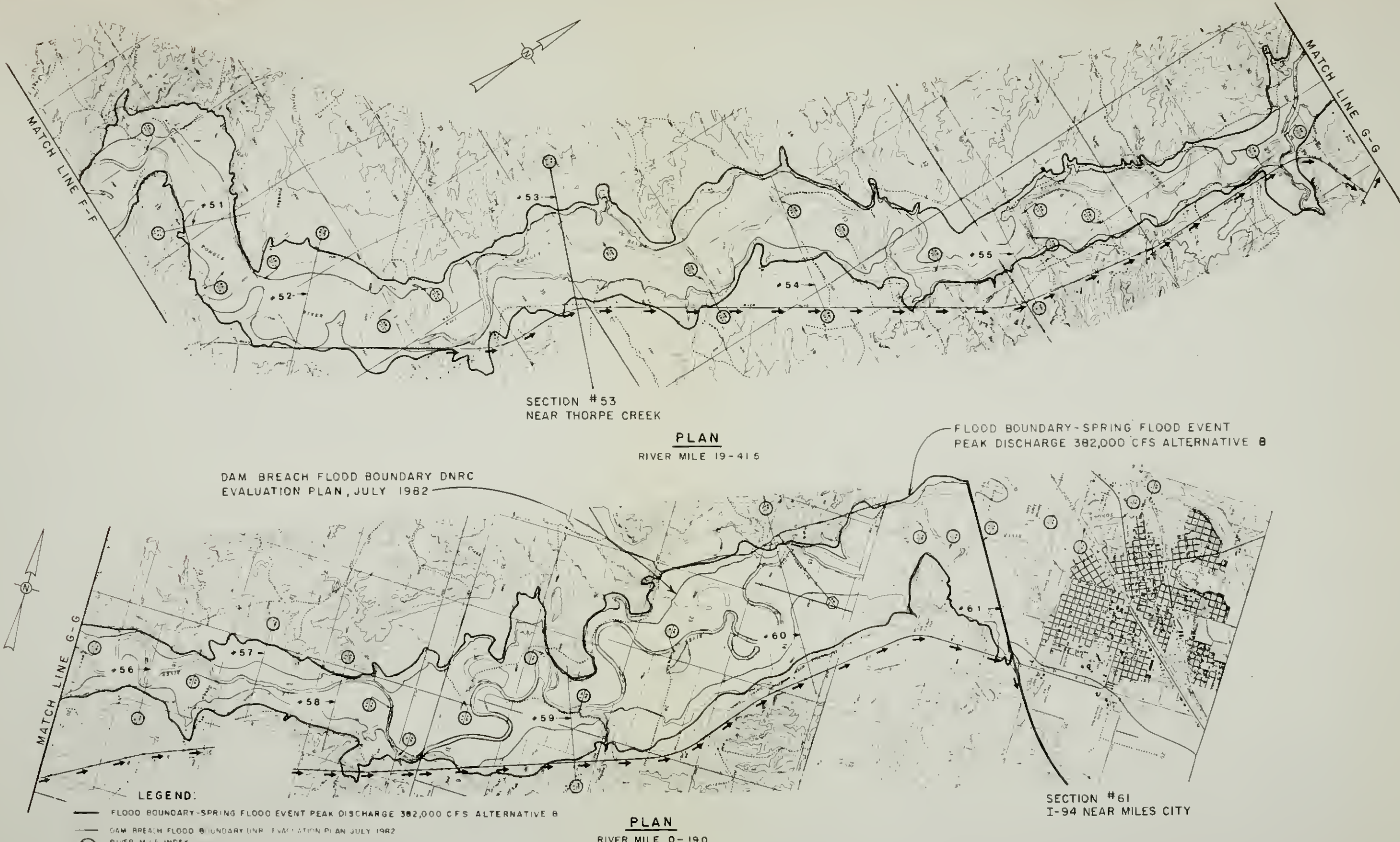
ION #61
NEAR MILES CITY

- FLOOD BOUNDARY-SPRING FLO
- DAM BREACH FLOOD BOUNDARY (IN
- RIVER MILE INDEX RIVER MILEAGE ABOVE MOUTH
- FLOOD ROUTING CROSS SECTION
- FLOODED ROAD SECTIONS
- EVACUATION ROUTES TO EMERGENCY
- BURIED GAS LINE CROSSING
- OVERHEAD POWER LINE CR
- BURIED TELEPHONE CAB

TONGUE RIVER DAM
RISK ASSESSMENT

FIGURE VIII-1 FLOOD BOUNDARIES AND PLAN AND CROSS SECTION DESIGNATIONS OF TONGUE RIVER

SHEET 4 OF 4



LEGEND:

- FLOOD BOUNDARY-SPRING FLOOD EVENT PEAK DISCHARGE 382,000 CFS ALTERNATIVE B
- DAM BREACH FLOOD BOUNDARY DNR EVACUATION PLAN JULY 1982
- RIVER MILE INDEX / RIVER MILEAGE ABOVE MOUTH
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- FLOODED ROAD SECTIONS
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- GAS LINE — BURIED GAS LINE CROSSING
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- TELE CABLE — BURIED TELEPHONE CABLE CROSSING

1/2 0
SCALE OF MILE

TONGUE RIVER DAM
RISK ASSESSMENT

FIGURE VIII-1 FLOOD BOUNDARIES AND PLAN AND CROSS SECTION DESIGNATIONS OF TONGUE RIVER

SHEET 4 OF 4

Because inundation studies were performed for the 1982 emergency warning and evacuation plan for the Tongue River Dam, data were available on channel characteristics of the Tongue River reaches. After a careful review of the available data used in the 1982 study, it was determined that the data were satisfactory for the present study. The U.S. Corps of Engineers' Hydrologic Computer Package, HEC-1, was used for breach analysis and floodplain delineation in the 1982 report. Therefore, it was decided to use the HEC-1 model for performing dam break and flood routing computations in the present study. The choice of using HEC-1 model was based on the following considerations:

- HEC-1 is consistent with procedures and data used in the 1982 emergency/evacuation plan.
- Massive amounts of channel cross-section data were available.
- HEC-1 provides for rapid calculation of multiple flood hydrographs.
- Requirements for additional data were minimal.

Breach Analysis

Breach parameters were needed for calculating breach outflow hydrographs using the HEC-1 computer model. The required breach parameters were: breach shape, breach side slope, bottom elevation of breach, base width of breach, breach development time, and reservoir water surface elevation at beginning of breach.

Assumptions regarding these parameters, except the reservoir water surface elevation, were obtained from relationships developed from data on historic dam failures published in the literature and used in the emergency action plan study. Sensitivity studies were conducted and judgement was exercised in selecting the appropriate values for these parameters. In order to achieve a consistency for comparing rehabilitation alternatives and to keep the variation of parameters to a manageable number, the following values for breach parameters were used in breach outflow calculations for all failure modes:

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- o HEC-1 provides for rapid calculation of multiple flood hydrographs.
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Assumptions regarding these parameters, except the reservoir water surface elevation, were obtained from relationships developed from data on historic dam failures published in the literature and used in the emergency action plan study. Sensitivity studies were conducted and judgement was exercised in selecting the appropriate values for these parameters. In order to achieve a consistency for comparing rehabilitation alternatives and to keep the variation of parameters to a manageable number, the following values for breach parameters were used in breach outflow calculations for all failure modes:

- Breach shape-Trapezoidal.
- Breach Side Slopes (V:H) - 2:1.
- Bottom elevation of breach (feet) - 3364.4.
- Base width of breach (feet) - varies from 500 to 1,000.
- Breach development time (hours) - 2.0.
- Reservoir water surface elevation - depending on loading condition under consideration.

Routing of Breach Outflow Hydrographs

For each flood event, the inflow hydrograph was routed through the reservoir and downstream to Miles City using the HEC-1 model. The outflow hydrograph through the breached dam was started when the reservoir water surface elevation reached maximum stage during routing of the inflow hydrograph through the reservoir. Spillway and outlet works rating curves for each rehabilitation alternative were developed and a reservoir storage-elevation curve was prepared using the latest data furnished by DNRC. All three curves were required in the reservoir routing computations.

Each flood event was considered to start with the reservoir level at the spillway crest elevation associated with the rehabilitation alternative being studied. The reservoir outflows (including breach outflow) were routed through the downstream river reaches. The peak flow, time to peak stage, the maximum stage, and the maximum velocity of flood flow at the downstream end of each reach were computed. Over 200 routing computation runs were performed to cover each loading combination, the four rehabilitation alternatives, the existing dam case and natural flows. In order to facilitate the assessment of economic damage associated with each loading condition and rehabilitation alternative, flood-stage curves were developed for eight key locations along the Tongue River using routing results for six typical loading cases shown in Table VIII-1. Flood-stage curves were prepared for cross-sections downstream of Dam (No. 4), Birney (No. 14), Birney Day School (No. 18), Ashland (No. 28), USGS Gage 6-3078 (No. 37), H.S. School (No. 45), Thorpe Creek (No. 53) and Miles City (No. 61). These locations are shown in Figure VIII-1. The flood-stage curves are shown in Figure VIII-2.

TABLE VIII-1

TONGUE RIVER DAM

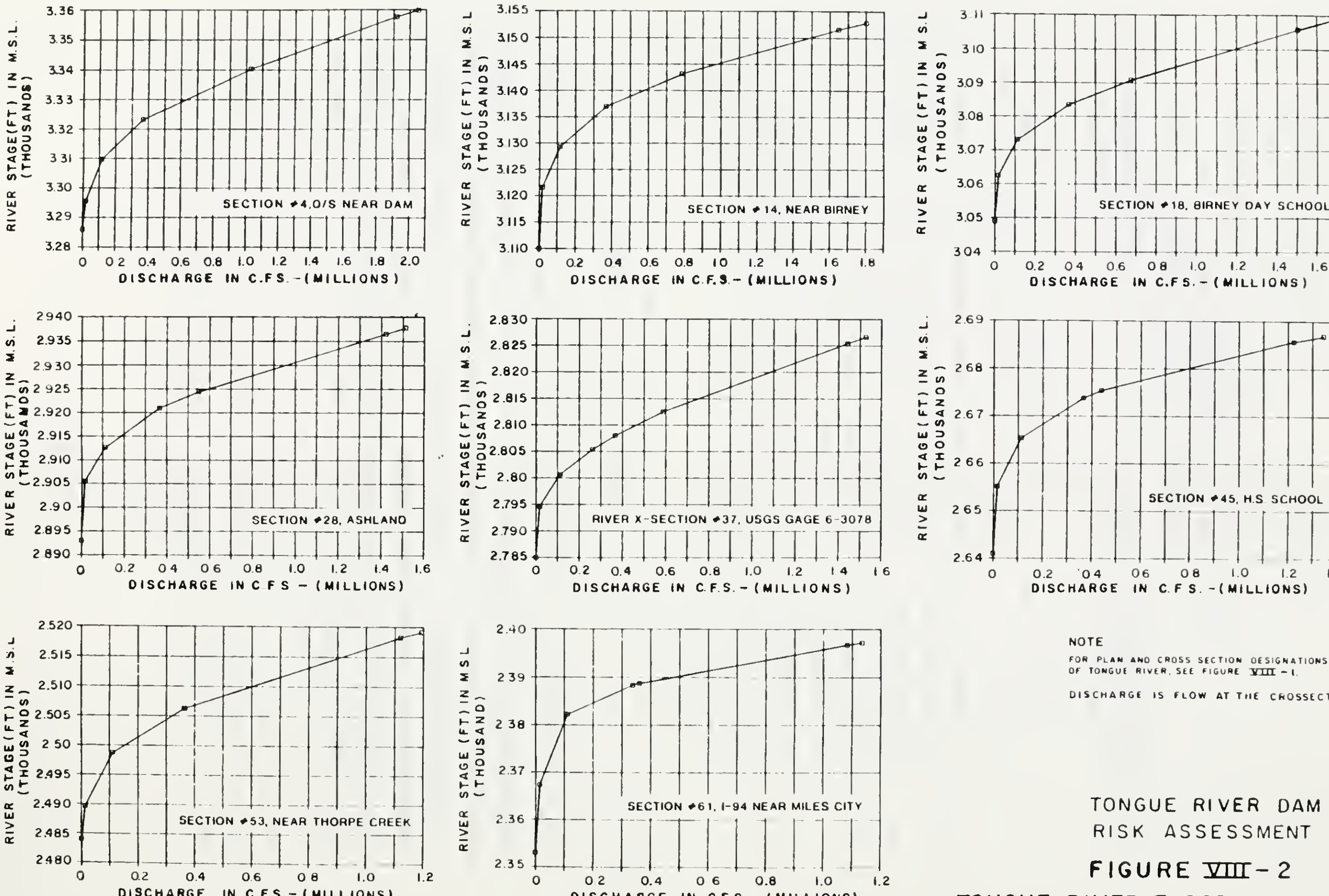
PEAK DISCHARGE IN C.F.S.
FOR DEVELOPMENT OF FLOOD-STAGE CURVES

Section No.	Section Location	River* Mile	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
	Reservoir Inflow Peak (cfs)		22,000	118,000	382,000	500,000	118,000	500,000
	Alternative		Existing (A)	Existing (A)	B	B	C	C
	Dam Breached (Y/N)**		N	Y	N	Y	N	Y
Start	Dam	189.1	18,043	1,197,662	367,827	2,266,286	113,385	2,166,909
4	D/S Dam	180.1	17,976	1,025,397	367,472	2,051,268	113,303	1,918,276
14	Near Birney	155.2	17,452	784,257	366,971	1,801,372	113,018	1,646,482
18	Birney Day School	143.5	17,170	677,013	366,546	1,680,230	112,805	1,503,333
28	Ashland	111.0	15,912	549,109	365,796	1,511,711	112,444	1,419,524
37	USGS Gage 6-3078	90.6	15,628	479,236	365,154	1,425,645	112,279	1,320,578
45	H. S. School	64.1	15,200	437,937	364,585	1,345,781	112,035	1,222,504
53	Near Thorpe Creek	31.2	14,461	365,353	363,030	1,192,815	111,311	1,119,090
61	I-94 Nr. Miles City	2.1	14,003	337,097	360,202	1,133,917	110,898	1,082,222

* Measured from confluence of Tongue and Yellowstone Rivers

** Failure condition: N = No; Y = Yes.

With the flood-stage curves for key locations along the river reaches, the preparation of an inundation map for each flood routing became unnecessary. However, for purposes of illustration and as a guide in assessing flood damages, inundation boundaries for the spring flood event with reservoir inflow peak of 382,000 cfs for rehabilitation Alternative B were delineated and are shown in Figure VIII-1. The inundation map for the 1982 emergency plan is also shown in Figure VIII-1 for comparison.



NOTE
FOR PLAN AND CROSS SECTION DESIGNATIONS OF TONGUE RIVER, SEE FIGURE VIII - 1.

DISCHARGE IS FLOW AT THE CROSSECTION

TONGUE RIVER DAM
RISK ASSESSMENT

FIGURE VIII - 2

TONGUE RIVER FLOOD RATING CURVES

C. Damage Assessment

The economic evaluation of alternatives for modification of the risk of dam failure is used primarily to assess whether projection above minimum design levels is economically justified. The justification can be based on the minimum cost for a level of protection, an incremental analysis where benefit to cost ratios are used to compare benefits with the costs of modification, or comparison of costs of modification alternatives and choice based on the minimum of the summation of annual risk cost and annualized modification costs. Each of these criteria is a measure of efficiency in expenditure relative to the benefits derived from risk modification.

The economic evaluation consisted of two parts. First an assessment of damage was made, and then the damage estimates were combined with the probabilities of the loading conditions and their resulting response probabilities to derive a risk cost for the damages in question. The economic evaluation used both information elements to compare the reduction of expected damages with the cost of achieving the reductions.

The quantification of flood damages required the identification of the floodplain and inundated areas for alternative magnitudes of floods projected for dam failure responses. Once those areas were identified, then land use characteristics and enterprise activities in the areas had to be determined. The extent of downstream damage was then estimated for alternative flood magnitudes using the land use characteristics and enterprise activity information along with estimates of damage-depth of water relationships and estimates of damages obtained from various public and private business and household sources.

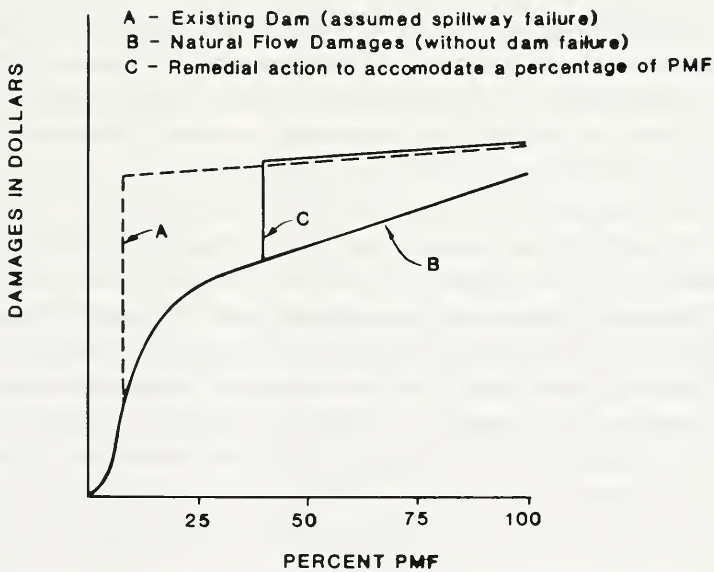
Damages were estimated for residential, commercial, industrial, public, and agricultural losses projected to result from inundation. In addition, estimates were made for losses of income or wages due to the flooding and the interruption of business activity. Impoundment project benefits which would be interrupted or lost were also included in the damage estimates. Residential losses included property damage and displacement costs for the time residences would be under repair for reoccupation. Commercial and industrial losses included capital losses and

employment and income losses. Public facility and service losses included property damage to buildings, health care facilities, transportation structures, utilities, and recreation sites. In addition to the cost of property damage and repair for these facilities, provision of temporary services had to be included. Commodities and services would have to be replaced and the cost of that replacement was added to the public facility damage estimates. Agricultural losses consisted of capital losses, crop and livestock enterprise income losses, and an estimate of lost productive capacity of land (the costs of replacing the land to original productivity was included for those areas which would experience serious erosion). Loss of reservoir benefits, such as recreation, irrigation, and municipal and industrial uses of water, were estimated for the period of time that project service would be interrupted by flooding and not operative until repaired. If the structure would be repaired, the cost associated with the repair was included in the risk cost.

In the present damage assessment for the Tongue River region, damages were estimated for all of the above categories. The damage estimates and descriptions of the circumstances or basis of the damages were presented by major community (Miles City, St. Labre Mission, Ashland, and Birney), public facilities, temporary housing replacement and wage losses, emergency costs, business income losses, losses to utilities, rural damages (primarily ranch crop and livestock income losses), and lost project benefits. Property damages can be estimated by using an extensive appraisal of property blocks within the floodplain which has been completed, or by initiating such an appraisal, or by relying on secondary information or a survey of information available including average values, incomes, and conditions in the affected region. This latter approach involves obtaining estimates of value and possible damage from various sources, including county clerk offices, realty firms, Corps of Engineers appraisal worksheets, business establishments, farm organizations, chambers of commerce, utilities firms, etc. Estimates derived for this study were developed using this latter approach since no previous appraisal was available. Estimates of damage are given in 1985 dollars to reflect the general level of prices for outputs and inputs prevailing in the period immediately preceding the analysis and to convert benefits and costs to constant dollar streams. The discount rate used for converting benefit or loss streams to present value, or for annualizing costs, was the federal discount rate as of October 1, 1986, of 8.875 percent, which

is in accordance with section 80(a) of Public Law 93-251. The rate reflects the average yield during the preceding federal fiscal year on interest-bearing marketable securities of 15 years or more remaining maturity.

There are three general types of damages which are of concern to decision makers in assessing the risk of loss due to dam failure and developing decisions to modify these risks. The first type of damage is the natural flow damage which occurs without dam failure. In the case of a project which includes flood control as a project purpose, natural flow damages could be replaced by baseline damages which include operational damages resulting from normal project operations of the impoundment. These damages precede dam failure and are not attributable to the uncontrolled release of the impoundment via failure. The natural flow damages are those represented by the outflow equals inflow condition (see Curve B in Figure VIII-3).



(Adapted from USBR)

FIGURE VIII-3 SCHEMATIC CURVES OF INCREMENTAL DAMAGES FOR ALTERNATIVE ACTIONS COMPARED TO NATURAL FLOW DAMAGES

There is no flood control for the Tongue River Dam and, therefore, natural flow damages are equal to baseline damages. The second damage estimate is the total damage resulting from failure of the dam and release of the impoundment (see Figure VIII-3). Using the damage estimates derived from the damage assessments described later, a flow-damage relationship (damage curve Figure VIII-5) was developed. For any given outflow the damages due to that flow can be read off the damage curve for damages due to natural flow and damages due to dam failure and release of the impoundment.

The natural flow damages are deducted from the gross downstream damages (due to failure and release of the impoundment). By so doing, the remaining damages represent those only associated with failure and impoundment release, which is normally interpreted as the extent of the responsibility of the project owner and operator.

A third classification of losses includes the possibility of punitive damages, compensatory payments, and legal fees that may or may not be associated with structural failure consequences. These losses were investigated in this study by reviewing the implied legal environment concerning responsibility of structural failure in the State of Montana (see Appendix A).

The specific limits of the areas studied for damages extended from the dam to the confluence of the Tongue River and the Yellowstone River at Miles City. The Yellowstone River is significantly larger than the Tongue River and the Yellowstone River valley is much wider than the Tongue River valley, and hence, the floodplain is also larger. The additional flows in the Yellowstone River valley below Miles City, resulting from flows contributed by the failure of Tongue River Dam, would not be expected to cause significant additional damages or alter the results of the risk assessment. Therefore, the damage study was terminated at the downstream reach of Miles City.

The damage assessments for this study were conducted on the basis of telephone surveys, windshield surveys, conversations with people in the areas, and information contained in reports. Several organizations were contacted including realtors,

chambers of commerce, school districts, hospitals, major businesses, county and state offices, insurance brokers, and the Corps of Engineers.

The damages were calculated for specific flood flows in order to generate a flow versus damage relationship. Some of the flows were further refined due to specific features in the floodplain. Although additional refinement of the flow-damage relationship would have been possible, it would have been very expensive and was not considered necessary for the scope of this study. The flow-damage relationship as developed was considered to be sufficiently comprehensive and complete for the level of the overall study.

In determining damages, it was important to remember that the physical arrangement of property in each area differed and the pattern of flood flows in Birney differs from the flows in Miles City. This was due to the attenuation of the flood over the study area of 187 miles. To be able to develop one curve or set of curves of damages versus flow for the entire study, a common flow denominator was defined. This common factor was outflow at the dam since the focus of the study was the dam. Each outflow was attenuated, however, to reflect actual flow patterns at each geographical area.

The damages were estimated under fifteen categories. These categories were the residential, commercial, and personal property damages at (1) Miles City, (2) Ashland, (3) St. Labre, (4) Birney, damages to (5) roads and bridges, (6) railroads and transportation delays, (7) schools, (8) hospitals, (9) temporary housing and lost wages, (10) emergency and evacuation costs for Miles City, Ashland, St. Labre, and Birney; (11) lost business income, (12) utilities, (13) rural damage costs, (14) lost project benefits, and (15) dam replacement costs. The methods of determining the damages for each of these areas are described in the following sections.

Miles City - Residential and Commercial (1)

The Miles City damage assessment was developed from information collected from a windshield survey; a telephone survey involving the Miles City Chamber of Commerce, the Board of Realtors, three realty firms, the Custer County Assessor's Office, the US Army Corp of Engineers (COE), and the

following reports; County Business Patterns 1983 and 1984, Flood Insurance Study, City of Miles City, Montana, Federal Emergency Management Agency, Flood Insurance Administration, August, 1979; Phase I General Design Memorandum Local Flood Protection Project, Summary Report, Yellowstone and Tongue Rivers, Miles City, Montana, COE, November, 1978; and Final Environmental Statement Local Flood Protection Project, Yellowstone and Tongue Rivers, Miles City, Montana, COE, December, 1978. The first step was to determine the approximate number of structures and a general breakdown of those structures in Miles City. Miles City has the largest population within the study area with an official 1980 census of 9,602 (US Census Bureau). An estimate of approximately three people per family was assumed to con-vert the general population to families per home. Based on the collected in-formation, the population, and county business patterns, an estimate of 3,000 homes and 350 business establishments in Miles City was obtained. There is a wide variation in residential property values, ranging from $9,000 to $225,000. With this wide range of property values it was difficult to determine the average values so a high average value of $55,000 per house and a low average value of $45,000 per home was used to calculate total residential property values. The businesses were valued at an average of $100,000 each. The total values of residential and commercial property values for Miles City were $200,000,000 and $170,000,000, high and low, respectively.

The next step was to determine the extent of the flooding and associated damage to the structures for each flooding event. Based on information in the COE reports for the levee system, the fairly level topography and the layout of the city, the following percentages of extent of damages were estimated. No damages were assumed to occur in Miles City as long as the levee system held (less than 14,000 cfs flowing in the Tongue River at Miles City). This corresponded to a reservoir outflow of 18,000 cfs. At a reservoir outflow of 21,000 cfs (17,000 cfs at Miles City), the levee system was assumed to have partially failed and 60% of the city was affected based on the COE reports. At reservoir outflows of 28,000 cfs, the levee system was expected to have failed and 80% of the city was estimated to have been affected. When the reservoir was discharging 113,000 cfs, it was estimated

that a maximum of 95% of the city was affected. With greater flows, it was estimated that no more than 95% of the city would be affected due to the geographical layout and topography.

The percent of damage was determined using FIA information, Flood Insurance Rate Review - 1985 Depth Percent Damage for Non-Velocity Zones. This information was computed based on averages across the country. When the information was compared to curves developed by the COE for the Western United States, Institute for Water Resources, US Army Corps of Engineers, Worksheets on Flood Damage and Depth of Flood, and for the Salt River in Arizona, Depth Damage Los Angeles District, US Army Corps of Engineers 1983 Salt River Flood Plain Study, the general curves were very comparable and were used in this study lacking specific data for Miles City. The percent of damage was determined based on a river stage producing an average depth over a percentage of the city. This value was compared with damages computed by the COE in the Local Flood Protection Report and found to be reasonable. Greater depths were experienced in the extreme flood events than are included in the information developed by the FIA and it was necessary to extrapolate the information. It was assumed that some residual value of property remains even if the structures were destroyed, estimated at 20%.

Percent damages were estimated for Miles City based on the FIA information and water depths taken from the flood routings: at 21,000 cfs outflow 15% damage; at 28,000 cfs outflow 30% damage; at 113,000 cfs outflow 60% damage; at 368,000 cfs outflow the damage was estimated at 75%; and at 1,120,000 cfs and 2,168,000 cfs outflow the damage was estimated at 80%. Dollar amounts were calculated by multiplying (area of city affected) by (total value of the city) by (percent damaged). The damage assessment included the personal property in the structures. The high and low values of the maximum damage costs for Miles City were $152,000,000 and $130,000,000, respectively. Table VIII-2 has the breakdown of the costs for the damage costs for Miles City, and all other areas examined, for all flood flow levels investigated. Figure VIII-4 graphically demonstrates the relative contribution of the damage costs of Miles City to the total damage costs.

TABLE VIII-2

TONGUE RIVER DAM
DAMAGE ASSESSMENT ESTIMATES

(Millions of Dollars)

Reservoir Outflow 1000's cfs	(1) Property-Residential and Commercial, Personal: Miles City	(2) Ashland	(3) St. Labre	(4) Birney	(5) Roads and Bridges	(6) Railroads and Transportation Delays	(7) Schools	Sub-Total
0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0
21	18.0* (15)**	0	1.48	0	0	0	1.77	21.25* (18.25)**
28	48.0 (41)	0	1.70	0	0	.11 (.09)	4.73	54.54 (47.52)
113	114.0 (100)	.24 (.13)	3.41	.35	1.01	3.57 (1.82)	11.36	133.94 (118.08)
368	142.0 (121)	.49 (.49)	4.77	.50	2.18	4.93 (2.65)	13.24	168.11 (144.83)
1,120	152.0 (130)	1.82 (.97)	5.68	.80	2.71	5.43 (2.85)	15.89	184.33 (158.90)
2,168	152.0 (130)	5.77 (3.10)	9.08	.80	2.71	5.43 (3.85)	17.86	193.65 (167.40)

Reservoir Outflow 1000's cfs	(8) Hospitals	(9) Temporary Housing and Lost Wages	(10) Emergency and Evacuation Costs	(11) Lost Business Income	(12) Utilities	(13) Rural	(14) Lost Project Benefits	Total
0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0
21	0	1.44	.97 (.39)	1.38	0	1.77	0	26.81* (23.23)**
28	2	1.59	2.49 (.99)	1.38	0	1.77	0	63.77* (55.25)**
113	5	4.77	5.90 (2.36)	42.58 (2.08)	.04	7.29	0	199.52* (139.62)**
368	8	4.77	7.39 (2.96)	42.58 (2.08)	.14	10.91 (9.61)	0	241.90* (172.39)**
1,120	12	36.53 (18.87)	8.02 (3.21)	43.20 (2.70)	.84	13.6 (12.36)	4.0 (.05)	302.52* (208.93)**
2,168	12	37.56 (19.07)	8.38 (3.35)	43.96 (3.46)	.84	14.4 (13.6)	4.0 (.05)	314.79* (219.77)**

* Values are based on high average costs.
** Values in parenthesis are based on low average costs.

Note: Some values were interpolated. See text.

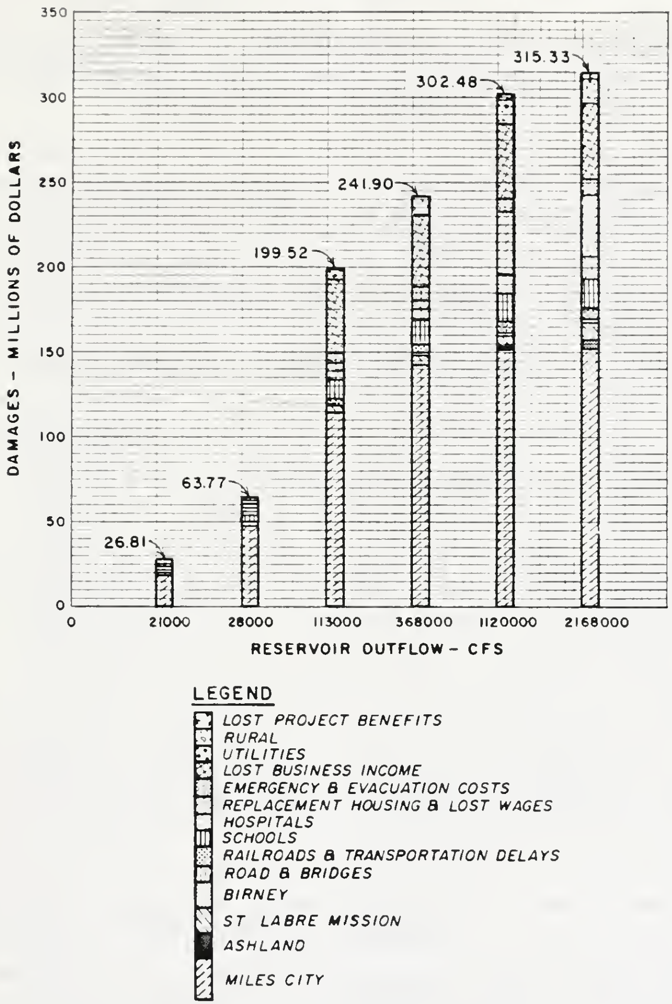


FIGURE VIII - 4
TONGUE RIVER DAM - DAMAGE ASSESSMENT
RELATIVE CONTRIBUTION OF COMPONENTS IN "INTERMEDIATE CURVE"

Ashland - Residential and Commercial (2)

Information for Ashland was collected from a windshield survey and a telephone survey, including the Rosebud County assessors, the Rosebud County appraisers, and the Rosebud County commissioners.

The 1980 US Census for Ashland was 564 people. Assuming approximately three people per family per home, the population estimated was equivalent to 188 homes and 18 businesses for Ashland based on information provided by a Rosebud County commissioner. It was also assumed that the average value of homes and business for Ashland was equivalent to Miles City -- $100,000 per business and a high average of $55,000 per home. The low average value of homes was computed using $30,000, to account for the possibility that home values may be lower in Ashland than in Miles City because Ashland is a smaller town. The topography around Ashland indicated a lower elevation by the river with the elevation rising rapidly at a distance from the river. Some of Ashland is built by the river, but from USGS Topographical maps it appeared that the majority of the town is built on higher ground away from the river. Percent of damages was based on the FIA depth damage information using depths from the flood routings. It was estimated that no damages would occur until the reservoir outflows reached 113,000 cfs. At that outflow, it was estimated that flood waters would affect the low lying areas west of town which translated to an estimated 10% of all structures with 20% damage. At outflows of 368,000 cfs, it was estimated that 10% of the city would be affected with a 40% damage expected. At a reservoir outflow of 1,120,000 cfs, it was estimated that approximately 50% of the town would suffer damage with an average of 30% damage. At outflows of 2,168,000 cfs, it was estimated that the flood waters would affect 95% of the town with an average of 50% damage. The estimated high and low values of the maximum damage costs for Ashland were $5,770,000 and $3,100,000, respectively. For a breakdown of the estimated damage costs at various flows refer to Table VIII-2.

St. Labre Mission (3)

Information for St. Labre Mission was based on a telephone survey of the St. Labre Parrish, the St. Labre School, and the Bureau of Indian Affairs.

The St. Labre Mission is on Northern Cheyenne Indian Reservation land. The mission buildings include the church, rectory buildings, a large school, cafeteria, homes for staff and dormitories for children attending the school as well as parking facilities, athletic fields, and storage sheds. Based on information provided by the Bureau of Indian Affairs (BIA), the replacement value of the mission in 1983 was approximately $11.4 million. The location of the mission in the river valley and the fairly level topography is such that once flood waters exceed bankfull, nearly all buildings would be expected to be affected. At 21,000 cfs outflow, the floodwater was modeled to exceed bankfull and would be expected to affect all buildings at the St. Labre Mission with an average of 13% damage. The percent of damage was determined from the FIA depth-damage information and floodwater depths determined from the flood routings. At outflows of 28,000 cfs, the average damage was expected to be 15%; at 113,000 cfs outflow, the average damage was expected to be 30%; at outflows of 368,000 cfs, the damages were estimated at 42%; when outflows are 1,120,000 cfs, the average damage was expected to be 50%; and at outflows of 2,168,000 cfs, the damages were expected to be 80%. The estimated maximum damage at St. Labre Mission is $9,080,000. The detailed breakdown of the damage costs is contained in Table VIII-2.

Birney - Residential and Commercial (4)

Information for Birney was developed from a windshield survey with an estimated population of 90 people. It was estimated that there were 30 structures both commercial and residential with a total estimated value of $1 million. The town is located on high ground on an outside bend of the river. These facts combined to give the town some flood protection and, therefore, no damages were estimated for reservoir outflows of 28,000 cfs or less. For

reservoir outflows of 113,000 cfs, it was estimated there would be 35% damage to all the buildings; at outflows of 368,000 cfs, the damage was estimated to be 50% to all buildings; and at outflows of 1,120,000 cfs or 2,168,000 cfs, it was estimated that damage would be 80%. The percentage of damage is based on PRC flood routings to determine an estimated depth and the FIA depth damage information. The estimated maximum damage costs in Birney are $800,000 and the costs at various other flows are identified in Table VIII-2.

Based on information provided by the BIA, the Birney Day School is no longer in use, and it was omitted from this study. It was also recognized that Brandenberg is located in the floodplain and damages for Brandenberg are included under rural damages.

Roads and Bridges (5)

Information regarding the roads and bridges was obtained by contacting the Custer County Public Works Department and the Montana State Department of Highways.

Of the 13 bridges in the study area that could be affected by flooding, three connect major thoroughfares and 10 are smaller bridges. Full replacement of the bridges in the event of complete damage was estimated at an average of $100,000 per bridge for a total estimate of $1.3 million. It was estimated there would be no damages at outflows of 28,000 cfs or less. At outflows of 113,000 cfs, it was estimated that there would be an average of $50,000 repair work for all 13 bridges. At this flow range, it was also estimated that there could be about 12 miles of road requiring repair work estimated at $30,000 per mile for a total damage of $1.0 million.

At outflows of 368,000 cfs, it was estimated that the three major bridges could require repairs of $100,000 each and the remaining 10 could require an average of $50,000 each. An estimated 18 miles of roads could require repairs estimated at $60,000 per mile and 10 miles estimated at $30,000 per

mile. At outflows of 1,120,000 cfs, all 13 bridges would likely require repairs, averaging $100,000, and road repairs could be 18 miles at $60,000 per mile and 11 miles at $30,000 per mile. With outflows of 2,168,000 cfs, the damages were estimated to be the same as for the preceding case. Table VIII-2 shows this information in a tabulated form.

Railroads and Trucking (6)

Miles City is a major center for transportation in the area. The Burlington Northern Railroad was contacted for information regarding its damage and delay costs and County Business Patterns was used to develop trucking costs. The Burlington Northern Railroad (BNRR) track goes over the Tongue River on a 316-foot-long bridge with between 10 and 16 trains using the track daily, a railcar maintenance company operates out of the Miles City switchyard using the BNRR track to bring cars to their business, and there are approximately 18 trucking firms operating out of Miles City. The railcar maintenance company was contacted, but no information was available from the company, so a value of the property and business ranging from $2 to $5 million was estimated. Damage percentages, as determined in Miles City for the residential and commercial property, were used to estimate approximate damage values for the railcar maintenance company. Damages to the maintenance company equaled 75% of the value and total damages ranged from 2.645 to 4.925 million dollars. Damages at outflows of 1,120,000 cfs or 2,168,000 cfs are 80% damage to the railcar maintenance company for a total cost of $2.845 to $5.425 million. In the event that the BNRR bridge was to be damaged, costs of repairs to piers and abutments were estimated to be $100,000. If the bridge were destroyed, the BNRR reportedly would put up a temporary bridge within 10 days and replace it with a permanent bridge afterwards. Therefore, delay costs were applied to the time required to build the temporary bridge. The cost of both the temporary and permanent bridges was counted in the damage costs.

The trucking industry was the least affected due to the anticipated quick reopening of roads in and out of the area. There were no damages antici-

pated for outflows up to 21,000 cfs. At outflows of 28,000 cfs, however, delay costs of one day to the businesses totalling between $89,500 and $107,500 were estimated. At outflows of 113,000 cfs, it was estimated that businesses could be affected for one week. Pier and abutment damage to the bridge was estimated at $100,000. Damages to the railcar maintenance company was 60% of the assumed value, for a total cost ranging from $1.819 to $3.565 million. A tabulation of damage costs for this area is shown on Table VIII-2.

Schools (7)

The Unified School District, the Ashland School, and Jefferson County Schools Construction Management, Colorado were contacted to develop information regarding number and size of schools in Miles City and Ashland and the costs to build schools of various sizes.

In Miles City, there are five public grade schools, one private grade school, one junior high school, and one senior high school. The only actual cost data available were for a recently completed grade school in Miles City for $1,517,000. In the absence of other data, the following assumptions were made based on information provided by Jefferson County Schools Construction Management in Colorado: a junior high school was estimated at three times the cost of a grade school due to its larger size and additional facilities, and a high school was estimated at four times a grade school. In Ashland, there is one grade school and one middle school and the costs were assumed to be the same as the costs for a grade school and a junior high school in Miles City. Extent of damages to the schools were assumed to be similar to their respective cities as a whole. Costs of damages to the school at St. Labre Mission were discussed previously. Refer to Table VIII-2 for the cost breakdown in this category.

Hospitals (8)

There are two hospitals, both located in Miles City, included in this study and both were contacted for information. The Veterans' Administration Hospital

(VA) has the following facilities located on the first floor: kitchen, clinics, canteen, outpatient offices, and administrative offices. The Holy Rosary Hospital has its computer room, x-ray, physical therapy, emergency, maintenance, administration and personnel offices, gift shop, and boiler rooms on the first floor or below. Although damage estimates were difficult to make, an estimated value of the equipment was used to estimate the following damages:

Outflows (cfs)	Damages (million $)
0	0
18,000	0
21,000	0
28,000	2
113,000	5
368,000	8
1,120,000	12
2,168,000	12

Temporary Housing and Lost Wages (9)

The cost of lost wages and replacement housing was estimated for Miles City and Ashland. An approximate 1984 personal income per capita of $3,912 per year was used for both Ashland and Miles City based on information contained in the County Business Patterns for Montana. An average cost of $25 per day per capita was used for replacement housing based on hotel and motel costs and assuming that some people could be housed by relatives, neighbors, and friends and some could live in motels or other government provided temporary housing. All the estimated values assumed were averages in spite of the fact that some people could experience disparities from the averages. At outflows of 21,000 cfs, 60% of Miles City was estimated to be affected. It was further estimated that the average loss of wages and replacement housing would occur for one week. No apparent damages were estimated for Ashland for this outflow. At outflows of 28,000 cfs, 80% of Miles City was estimated to be affected; loss of wages and replacement housing was based on an average of one week duration, and once again no damages occurred in Ashland. At 113,000 cfs outflow, it was assumed that

one week's wages would be lost for both Ashland and Miles City and that one week replacement housing would be required in Ashland and one month required for Miles City. At 368,000 cfs outflow, the lost wages and replacement housing were estimated to be the same as for the previous case.

At 1,120,000 cfs outflow, it was estimated that two weeks' wages would be lost in Miles City and one week's wages in Ashland. An average of one month replacement housing was estimated in Ashland, and in Miles City a range of three to six months was estimated. At outflows of 2,168,000 cfs, the same figures were used for Miles City. For Ashland, the values were estimated at one week's lost wages and a range of from one to three months replacement housing. Dollar costs are shown in Table VIII-2 for the various flood flow levels.

Emergency and Evacuation Costs (10)

Emergency services and evacuation costs were difficult to estimate because of limited information compiled by the State of Montana and the COE and were, therefore, compiled only for some areas. Generally, it was estimated that they ranged between 2% and 5% of the residential and commercial property values. The value of emergency and evacuation costs were determined by multiplying the 2 or 5% by the sum of the residential and commercial damage costs in Miles City, Ashland, Birney, and St. Labre Mission. The costs of these services are tabulated in Table VIII-2.

Lost Business Income (11)

Each flood event causes economic losses to urban businesses in addition to property damages or damage to capital such as structures, equipment, and inventory. The economic losses include wages lost for a temporary period, and net business income which is either a temporary loss or a loss for the 53-year planning horizon (remaining life of the dam structure) if the businesses are not recovered because of the flood. The derivation of wage losses was discussed earlier. Business income losses which are included in the damage estimates are discussed at this point.

Net business income was derived from receipts and expenditures information included in the Census of Manufactures: Geographical Area Series, Annual Survey of Manufacturers, Census of Wholesale Trade, Census of Retail Trade, Census of Service Industries: Geographic Areas Series. Payroll information from County Business Patterns and information on establishments, payroll, receipts, shipment, materials, and intermediate goods expenditures from these secondary sources above were supplemented with information from a telephone survey of specific representative businesses. The survey provided information on net incomes of average non-farm business establishments in Miles City and Ashland. Some information was obtained from businesses in Billings, Forsyth, and Broadus, Montana and Sheridan, Wyoming where chains, franchises, and subsidiary business connections were involved.

Net income was calculated as receipts net of intermediate goods, transportation, and payroll expenditures. For the service industries, these calculations were derived from receipts and expenditures per employee from the census information. The receipts were updated to a 1985 base using the Producers Price Index for wholesale goods and manufacturers and by the Consumer Price Index for retail trade receipts. Expenditures were likewise updated using the Producers Price Index for certain manufacturers and the Consumer Price Index was used to update payroll expenditures. These net income calculations, for average establishments within each type of industry or trade category (services, manufacturing, transportation, wholesale, and retail trade, etc.), were then disaggregated to a weekly basis from an annual net income estimate in order to apply the estimated lost income for the number of weeks without income incident to the potential flood disruption.

In general, all establishments were projected to lose business income for at least one week, the same period of disruption as assumed for wage losses. Some establishments, however, particularly wholesale businesses, suggested in the phone survey that their recovery period would be quicker because the wholesale trade could continue within hours of opening transportation routes in from Billings, Sheridan, Helena, and Great Falls, as well as usual wholesale transactions coming from larger business centers such as Denver, Colorado and Salt Lake City, Utah. Representative manufacturing establishments

suggested it would take upwards of two weeks to reestablish production lines, but some trade would be covered by other plants of the same chain or other subsidiaries. The service industries would also take up to two weeks to reinitiate service to Miles City and Ashland, but again, services and some employment would come from other plants or establishments in nearby trade centers. Motel services would provide minimum shelter services during a major flood event, but then would have to close for repair during flood cleanup.

Miles City is the location for a considerable contract construction industry which services the region of eastern and northeastern Montana. A major flood would cause disruption of such services from the Miles City location for up to two weeks; however, some key services from the industry could be provided by each of the establishments from other satellite locations in the region, even though the industry would not be at full capacity. Much of the contract construction would be mobilized for cleanup and construction in later periods following the major flood event, if it were to occur.

Lost business income varied dramatically depending on the assumptions made concerning permanent loss of business. The phone survey and discussions with some industries suggested that there could be a permanent loss of retail trade establishments. It was hard to predict the location of business, particularly relocation incident to some hazard such as flooding. There was some indication that approximately 10% of the retail establishments would suffer such a large inventory loss, during a major flood in Miles City, that recovery would be in doubt. Therefore, two estimates of lost business income were made, one without permanent loss for the planning horizon and one including the discounted loss of 10 percent of the net business income for retail establishments over the remaining planning horizon. The lost business income then ranged from approximately $1.8 million to $40.5 million. The latter loss assumed that approximately 10 percent of the retail establishments would go out of business, and that the income lost from such an exit would not be replaced for the remaining planning horizon. The incomes lost from these businesses were discounted using the federal discount rate to arrive at a present value of the lost income. This value was relatively significant

compared to the temporary business income projected to be lost due to the incidence of flooding in the Miles City and Ashland areas. Refer to Table VIII-2 for a tabulation of lost business income.

Losses to Utilities (12)

Utilities' losses included electric power, natural gas lines, telephone cable, electrical substations, water treatment and sewage system damages, repair and temporary service costs, and repair of transmission lines in Miles City, Ashland, Birney, and in the path of the flood in the narrow valley through which the Tongue River flows. There were also power losses projected to occur in Forsyth and Broadus, which are communities located outside of the Tongue River region but they connected to utilities systems in the valley delivered by Montana-Dakota Utilities and the Tongue River Rural Electric Association.

Power outage losses were estimated as the quantity of kilowatts delivered per day times the average price per kilowatt times the delivery areas times two days disruption. Added to these losses were inventory losses estimated for the period of disruption and the cost of temporary services from diesel generators. Estimates of damages to the water treatment facilities and sewer works were obtained from municipal officials and were checked with COE damage information. Temporary service costs were added to these costs. Then, utilities service delivery structure damage and repair costs were accounted for each evacuation plan area of the Tongue River Dam Emergency and Evacuation Plan system by interview with Montana-Dakota Utilities, Mountain Bell, and the Tongue River Electric Association and Range Telephone cooperative. The losses were between $42,000 for the 113,000 cfs outflow case, $143,000 for the 368,000 cfs case and $840,000 for both the 1,120,000 cfs and 2,170,000 cfs outflow cases. These estimates assumed that the Ashland electric substation would not be completely replaced and that scouring of the land in the river reach below Ashland would likely be much less than in the upper reaches of the river, just below the dam. Damages for each block or reach of the Tongue River, as defined in the Tongue River Dam

Emergency Warning and Evacuation Plan, averages approximately $19,000 per reach. Table VIII-2 contains the estimated losses for each flood increment considered.

Rural Damages (13)

Damages in the rural reaches of the Tongue River were mainly due to the temporary cutoff of incomes derived from the production of range livestock and associated crops used for the livestock enterprise which pervades the valley and surrounding rangelands. Damages for the ranch homes and ranch headquarters structures and equipment were also estimated. Additionally, estimates of the reduction of the productivity of the cropland incident to the major flood events and the costs for restoring the productivity were added to the crop, livestock, and ranch structure damages. Canal and ditch works damages and cost of repair were also included.

Loss estimates for crop production (mainly used in the livestock enterprise) and livestock activities were derived by using the Bureau of Reclamation budget information contained in the Tongue River Dam Study: Appendix D, Economics. Budgets for estimating the benefits of new water supply from the Tongue River were developed by the Bureau for both crop and livestock enterprises for the region. The price information associated with the budgets was updated to 1985 to reflect the nearest entire year to the dam safety decision year (1986). Updated production input information and product sales information were included in the revised budgets.

Crop losses included losses due to inputs such as seed, fertilizer, labor, and machine work. They also included the losses of net crop income which stopped temporarily due to the flood. The livestock income is calculated as income on a brood cow basis which included the sales of calves, replaced cows and bulls, and some yearlings as assumed in the budgets developed. Brood cow herd size varied on the Tongue River valley ranches, but exact information on herd size for all of the ranches accounted for in the floodplain was not available. Therefore, similar to the assumption in the Bureau

budgets, a common herd size was assumed as representative of the livestock enterprise in the region. All losses were derived from this common livestock unit and, therefore, crop production unit.

Since there was no detailed report of flood damages developed for the entire Tongue River area, composite flood damage loss percentages which have previously been developed for the western United States by the U.S. Army Corps of Enginers were applied to the net income, input price levels, and value of livestock units in order to obtain estimates of crop and livestock damages. These percentages reflected depth of flood/percent loss relationships for agricultural activities. Therefore, once the depth of any particular flood stage had been calculated, those percentages could be applied to the agricultural values developed from the budgets to estimate loss. Once it was determined how many livestock units were lost, i.e., brood cow units lost, then using the feed conversion ratios of the budgets and the amount of feed needed as suggested by the budgets, the additional purchase of feeds (barley and hay) costs were calculated and added to the damages. Losses varied according to the depth of flood at various locations. The losses varied in relation to the flood attenuation as modeled in the hydrologic phase of the study.

Ranch headquarter structural damages and damages to equipment and other capital were also added to the crop and livestock losses. Ranch homes and adjoining structures, such as garages and other household buildings, were included. Depth/damage relationships derived from the U.S. Army Corps of Engineers were applied to the values of these structures to derive damages at the various flood stages modeled.

Damages represented as reduced productivity of the land due to scouring were also estimated. The Bureau of Reclamation land development costs, as contained in the Bureau budgets, were used and updated with information from the Soil Conservation Service and Extension Service at Montana State University to develop the costs of redeveloping the crop land to replace productivity. The Soil Conservation Service provided some guidance on the extent of scouring.

Following these estimation procedures provided a range of rural damages for each reservoir outflow estimate. The damages ranged from $1.8 million for the 28,000 cfs outflow; $7.3 million for an outflow of 113,000 cfs; $9.6 million for 368,000 cfs; some $12.4 million for outflow of 1,120,000 cfs; and $13.6 million for an outflow of 2,170,000 cfs. Using information from discussions with ranchers and the Montana Extension Service, some projections of livestock operations, which would leave the industry as a result of extensive flooding, were developed. This adverse effect of flooding was particularly important in the upper reaches of the Tongue River region. The incomes from these lost operations would be lost for the remaining planning horizon and, therefore, these losses were discounted by the federal discount rate to provide a present value of the losses. These were added to the rural damage estimates and provide an upper range of losses on the ranches due to flooding at the more severe levels. Therefore, damages at the 368,000 cfs outflow level ranged up to $10.9 million assuming losses of some ranches; $13.6 million for the 1,120,000 cfs outflow and $14.4 million for the 2,170,000 cfs outflow. Losses for all flood levels are shown in Table VIII-2.

Lost Project Benefits (14)

In addition to property damages, loss of reservoir benefits were also included in the damage estimates. Reservoir benefits would be lost for a particular period of time following the failure of a dam structure. This period depends on an estimate of the rebuilding horizon and the decision to rebuild the dam structure and continue operation of the impoundment. The loss of such benefits may be viewed on the basis that they are lost permanently (over the economic life of the structure), or on the basis that the structure will be repaired or rebuilt. If the structure is to be repaired, the cost of repair is to be included in the risk cost.

For this particular impoundment, the benefits of the project consist of recreation use of the reservoir and the irrigation water delivered to the Tongue River Water Users Association and the Northern Cheyenne Tribe. The recreation benefits were in the form of user days on the reservoir and

can be valued (following the Water Resources Council Principles and Guidelines) by one of three valuation methods depending on the recreation resource information available, and whether or not valuation studies had been done which included the particular impoundment of interest. The three methods included the travel cost method of valuing instream uses of water projects; the contingent valuation survey method (sometimes referred to as the bidding game method of imputing willingness to pay); and the unit day value method. Because detailed travel costs and contingent valuation studies which particularly identified the recreation experience on the Tongue River reservoir were unavailable, the Principles and Guidelines unit value day method was used to sketch the instream valuation of the user days enumerated at the reservoir by the Montana Department of Fish, Wildlife and Parks. This same department completed 942 interviews of sport fishermen in 1983 which were appropriately used for valuing the sport fishing activity by the travel cost method, but there was not enough information to detail the Tongue River recreation potential to be useful in this estimation exercise.

The general recreation guidelines for assigning recreation experience points (from the Principles and Guidelines) was used to assign the points per user day for the Tongue River recreation type. Then a unit day value was derived from the points/value table and updated using the Consumer Price Index to a 1985 value. This value was then applied to the number of user days to arrive at an annual value of the instream use on the reservoir. This value provided a stream of recreation benefits for the period of time between dam failure and repair which was discounted to present value.

The contractually stored irrigation water (40,000 acre feet) was valued using two methods. One method provided a low estimate of the value of the water in use, and the other provided an imputed value in use which reflected the marginal contribution of the irrigation water in agricultural use. The latter was imputed by using the updated income values for crop and livestock production provided by the Bureau of Reclamation budgets. The low value of the water was calculated by applying the Tongue River Water Users Association repayment rate per acre foot for the original delivery of the water from

the Tongue River Project ($1.30 per acre foot). The higher value ($17.85 per acre foot), which reflected the marginal value of the water in current use, was calculated using an updating of the Bureau budgets.

The estimated recreation value and the irrigation value of the water from the project were added to provide an estimate of lost project benefits should the dam fail. The range of lost project benefits was from $658,000 to approximately $4,000,000 depending on the particular value that was used to value the irrigation water.

Dam Replacement Costs

The cost to rebuild the dam was also a factor in the damage assessment. The decision to rebuild is not a foregone conclusion although it was included in the damage function as a risk cost. The damages of lost project benefits, rural damages, and lost business income were developed based on the assumption that the dam would be rebuilt after seven years. The damages were based on outflow from the dam, and because the dam would fail at different outflows for each of the alternatives, the damage cost to rebuild the dam was handled as a separate calculation. This also facilitated understanding its contribution to the risk cost. DNRC estimates that it would cost 150 million dollars to rebuild the dam.

Summary of Damage Assessment

The breakdown of damage estimate costs for each defined area is summarized in Table VIII-2. In some areas it was very difficult to define the damage costs and therefore a low damage cost (shown in parentheses) and a high damage cost were computed. The totals shown on Table VIII-2 were then used as the low and intermediate damage assessment estimates in Table VIII-3.

TABLE VIII-3

TONGUE RIVER DAM
DAMAGE ASSESSMENT ESTIMATES

Reservoir Outflow (1000's cfs)	Damages in Millions of Dollars		
	Low	Intermediate	High
0	0	0	0
18	0	0	0
21	23.23	26.81	34.85
28	55.25	63.77	82.90
113	139.62	199.52	259.38
368	176.39	241.90	314.47
1,120	208.93	302.48	393.22
2,168	218.81	315.33	409.93

Low values are based on low average damage costs.

Intermediate values are based on high average damage costs.

High values are obtained by multiplying the intermediate values by a factor determined from the experiences of Teton Dam claim settlements.

Information from the experience of the Teton Dam failure in 1976 was investigated through contact with the US Bureau of Reclamation and a high damage assessment estimate was developed (see Table VIII-3). Curves of peak outflow at the dam versus downstream damages using the low, intermediate, and high values of Table VIII-3 were then developed and are shown in Figure VIII-5.

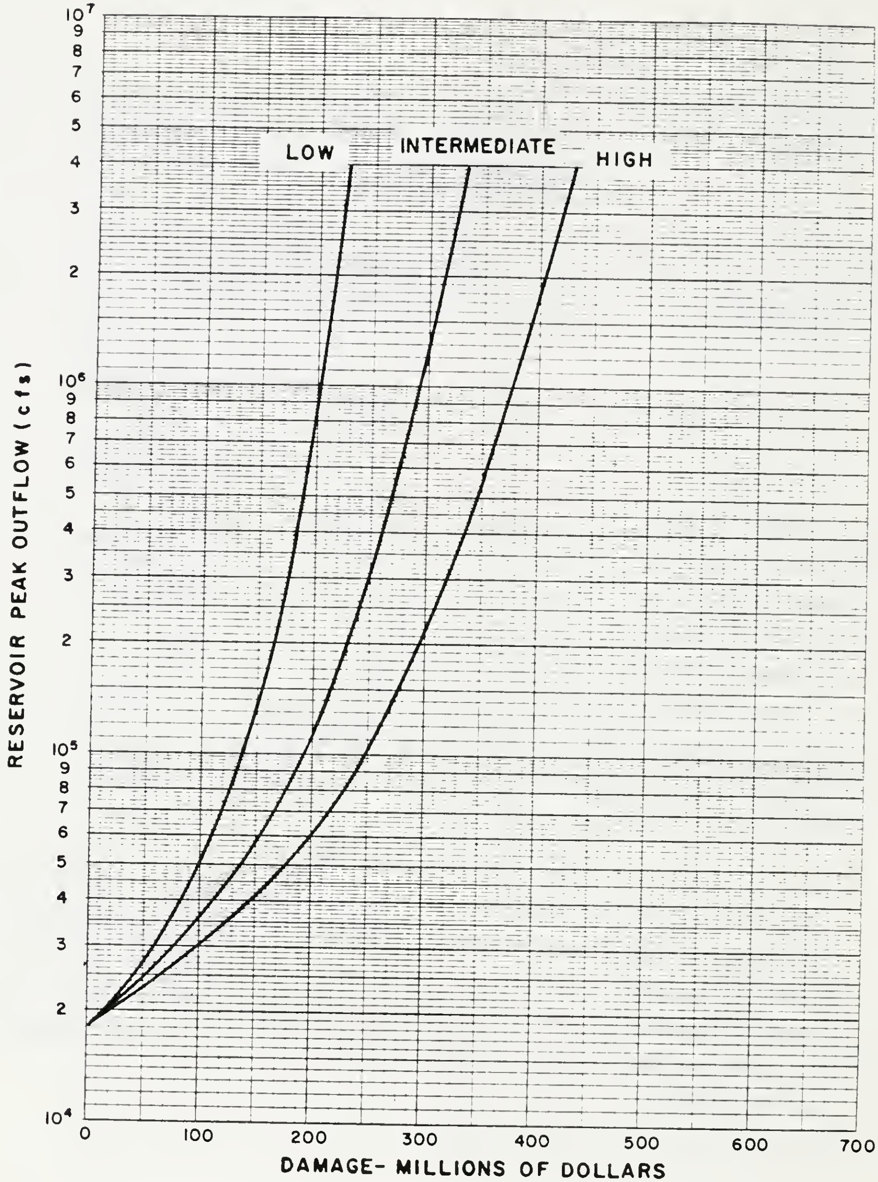


FIGURE VIII - 5
TONGUE RIVER DAM-DAMAGE ASSESSMENT

D. Threat to Life

Another important aspect in assessing the consequences of dam failure is the assessment of the threat to life.

The threat to life was described by estimating the populations at risk (PAR) in reaches downstream of the Tongue River dam and the likelihood of life loss in a failure event referred to as the exposure probabilities. Five steps were taken to characterize the potential loss of life due to dam failure.

First, the hydrological events were modeled and the flood attenuated for each event from the dam past each important population center of the Tongue River to Miles City. Flood depths were estimated for each event for each reach. The population and conditions of exposure to the floods were estimated using the 1980 Census of Population, updated using telephone survey information from people and agencies familiar with the population base and the communities exposed to potential flood events. Six exposure areas were identified downstream of the dam. The first, a short distance below the dam, included 11 residences in the direct path of flooding which would take place by overtopping of the dam or severe land scouring from failure of the spillway. The second was the small community of Birney and the area known as the Birney Day School. The third was the rural area between Birney and the town of Ashland. The fourth were the towns of Ashland and St. Labre Mission. The fifth was the rural population located between the St. Labre Mission and Miles City and the sixth and largest was Miles City.

The second step was to investigate the warning time that each population at risk (PAR) would have under hydrologically, seismically, and statically induced failures. Advanced warning significantly affects the magnitude of the threat to life. Considering the warning system, as outlined in the Tongue River Dam Emergency Warning and Evacuation Plan, and discussions about the warning system with Disaster and Emergency Services at both the state and county levels, it was estimated that areas between Birney and Miles City would have at least one and one-half hours of warning time for evacuation in case of a hydrologic event. The warning time for the reaches just below the dam, and in the town of Birney, would

also be approximately one and one-half hours for hydrologic events; but because evacuation routes from the ranches just below the dam could be partially damaged at high flood stages, the evacuation process could be delayed.

Although the probability of a Tongue River Dam failure, due to a seismic or static loading event, is much less than for hydrologic events, the warning time in the upper reaches below the dam was estimated to be somewhat less than one and one-half hour for failures due to seismic or static events. Therefore, the exposure of the PAR is higher for these events.

The third step in investigating the potential threat to life was to estimate the exposure probabilities as a function of warning time. There are two methods currently available for estimating these probabilities. One method is to use the historical relationships developed by the Bureau of Reclamation (Guidelines to Decision Analysis, Technical Memorandum No. 7) whereby loss of life for historical floods is related to warning time and population at risk. Two equations were estimated using the historical flood-loss of life data base developed by the Bureau and distinguished by the warning time being less than 1.5 hours and greater than 1.5 hours warning. The data base used to estimate the relationships included mostly rural or small communities, the largest populations being 23,000 and 58,000.

The other method that can be used is the U.S. Army Corps of Engineers Institute for Water Resources method which is a modification of the Federal Emergency Management Administration method for rural areas. This method has been adapted to more urban floodplains. The proportion of remaining threatened population of the total PAR is related to warning time. The loss of life per event is estimated from the remaining threatened population by relating the probability of loss of life to depth of inundation. These probabilities are more representative of an open and relatively flat floodplain, commonly found in large urban areas. If conditions are such that there are alternative evacuation routes, (i.e., several community streets leading to a few major freeways), then curves of threatened population remaining after the initial flood event occurrence can be developed. The curves relate remaining population exposed to hours after the event and evacuation route configuration. This method was not particularly applicable to the rather narrow

Tongue River Valley and the evacuation routes and plan which exist for this region. Therefore, the Bureau's historical relationships were used with some modifications for population exposure and evacuation potential existing in the region.

The fourth step was an investigation of the site-specific information on the exposure of the PAR. The information used was the same as that obtained to estimate property damages since property exposure and populations associated with these blocks of property in the valley were associated. The PAR exposure conditions were delineated for seven reaches of the Tongue River floodplain. Those reaches included the area just below the dam, the community of Birney, the rural reach from Birney to Ashland, Ashland, St. Labre Mission, the rural reach from the mission to the outskirts of Miles City, and Miles City. The exposure for the first two homes just below the dam and the remaining nine residences (ranch headquarters) were all estimated to have about the same exposure conditions. There was a day, night, and weekend exposure differentiation made for the St. Labre Mission and school, since only small proportions of the population would likely be at the mission or the school on the weekend. Also, several students and staff usually return to other communities outside the floodplain at night.

It was assumed that, on the average, there would be three persons per household in the floodplain. Using this assumption, time-weighted PAR's were estimated for each of the seven river reaches from the dam through Miles City. The estimated PAR's were 24 from the dam to Birney, 90 in Birney, 45 between Birney and Ashland, 564 in Ashland, 112 associated with the school at St. Labre, and 146 associated with the Mission at St. Labre. Then the population at risk is estimated at 127 for the reach between the mission and Miles City and 9,602 in Miles City.

The fifth step was to relate the estimated exposure probabilities for each reach using the Bureau of Reclamation method. The estimated PAR's and exposure probabilities were then aggregated into two general exposure regions of the valley from the dam through Birney and the reach from Birney through Miles City. The exposure probability for the upper reach reflected a weighted average probability of life loss exposure considering 1.5 hours of warning time for the hydrologically

induced failures and less than 1.5 hours of warning for the seismically and statically induced failures. For the lower reach the exposure probability reflected the 1.5 hours of warning time. The exposure probabilities, Column (18) (Table IX-1) on the spreadsheet were estimated as follows:

	Exposure Probability	
Population at Risk	Hydrologic Failure	Seismic and Static Failure
Dam - Birney	0.075	0.1500
Below Birney	0.0002	0.0002

The potential life loss per event for the hydrologically induced failure over all regions of the floodplain was estimated to be 11 lives. The potential life loss per event for the seismically and statically induced failures is approximately double that for a hydrologically induced failure. The pathway probability (product of the event, response, and outcome probabilities) provided an estimate of the annual probability of the life loss event occurring. For the existing Tongue River Dam, the annual likelihood of these life loss events occurring are 1 in 270, 1 in 1,000,000 and 1 in 19,100 for hydrologically, seismically, and statically induced failures, respectively.

IX. RISK ASSESSMENT COMPUTATIONS

A. Introduction

Estimates of risk costs and probability of life loss were made for each Alternative B, C, D, E to compare the risk associated with the Tongue River Dam under the existing conditions (Alternative A) and to estimate the risk reduction expected from each rehabilitation alternative. Descriptions of the five alternatives are presented in Section VII. The calculation of risk costs required estimates of the probabilities of occurrence of the various failure modes and the consequences associated with each failure mode.

The following steps were involved in the risk assessment and in the total risk cost computations:

1. Risk identification which included determination of the range of loading conditions, types of system response, and types of outcome.

2. Estimation of the probability and consequence components of risk and the exposure probability of the population at risk.

3. Establishment of the risk cost and life loss associated with each failure mode over the range of potential loadings.

4. Quantification of total risk costs.

Detailed discussions of Steps 1 through 3 above were presented in preceding sections of this report. In the following paragraphs, the risk analysis computations are discussed, including details of the risk assessment model, computational procedures, and results of the computation.

B. Risk Assessment Model

In order to facilitate the computation, a risk model (see Figure VII-1) was developed for the Tongue River Dam and reproduced in the computer using the

Lotus 1-2-3 electronic spreadsheet. The risk assessment spreadsheets for all the alternatives are included in Appendix B. Example Tables IX-1 through IX-1D are grouped at the end of this section for explaining the computation steps.

The computations as they appear in the tables are presented under the following major headings:

- o Loading
- o System Response
- o Outcome
- o Economic Damage
- o Threat to Life

These headings also have subheadings associated with each and are explained in the following outline:

Loading

A. Event Type: Risk identification is the first step in risk assessment. Furthermore, the assignment of event type and ranges of loading are the first task in the risk identification process. Four types of loading events were considered in this study: 1) spring floods, 2) summer floods, 3) seismic and, 4) static. Detailed discussions on these loadings are presented in Section V - Loadings. The hydrologic events were further broken down into 11 ranges under Column (1) for both the spring and summer flood events.

The seismic events were grouped into two categories based on magnitude of earthquake. The ranges are from M0 - 5.5 and greater than M5.5.

The static events were divided into five types according to the following failure modes which were assumed to be independent:

1. Foundation failure.

2. Failure due to piping not associated with the outlet works.

3. Failure of embankment slope due to deformation.

4. Failure due to piping associated with the outlet works.

5. Failure due to landslide into the reservoir.

B. Event Probability. The calculation of risk cost requires estimates of the annual probabilities of occurrence associated with the loading conditions. The event probabilities are shown under Column (2) in the spreadsheet.

System Response

Response type (failure mode) is shown in Column (3) of the spreadsheet.

For each hydrologic event, the following system responses were considered:

- No failure and partial failure.
- Spillway crest failure.
- Tailrace channel erosion.
- Piping through clinker.
- Overtopping.

The following system responses were considered for seismic events:

- No failure and partial failure.
- Reservoir landslide.
- Foundation liquefaction.
- Embankment deformation.
- Core cracking and piping through core.
- Rupture of the outlet works.

System responses associated with static loadings were:

- No failure and partial failure.
- Embankment deformation due to foundation failure.
- Piping through embankment.
- Embankment deformation due to slope failure.
- Outlet gate failure due to piping through outlet works.
- Seiche.

The response probabilities are conditional probabilities, associated with each of the response types discussed in the above paragraph, which were presented in Section VII. Values presented in that section were entered in Column (4) of the spreadsheet. The determination of the response probability was based on the conditions of the dam and reservoir system, considering the applied loading conditions for each rehabilitation alternative analyzed.

Outcome

A. Outcome Type. The outcomes associated with each system response were no failure, partial failure which involves damages to the structure but no release of the reservoir contents, and total failure which is the release of the reservoir contents. Shown below are the total failure outcome types associated with each system response for hydrologic events:

Response Type	Outcome Type
Spillway Crest Damage	Failure of Spillway and Dam Breach
Tailrace Erosion	Failure of Stilling Basin and Dam Breach
Piping through Clinker	Failure of Spillway and Dam Breach
Overtopping	Dam Breach by Erosion

These outcomes are shown under Column (5) in the spreadsheet.

Dam breach was considered the only failure outcome related to seismic and static loadings. In entering the outcomes on the spreadsheet, the no failure and partial failure outcomes were lumped together and shown in the first row of each loading section.

B. Reservoir Stage. The inflow hydrograph for each hydrologic loading Column (6) was routed through the reservoir/spillway system. The maximum reservoir surface elevation during the passage of the inflow flood is the reservoir stage shown on the spreadsheet under Column (6). The spillway crest elevation was assumed as the reservoir stage when dam failure occurs for seismic and static events. This is consistent with current USBR practices and will be conservative if the actual reservoir stage is below the spillway crest.

C. Outcome Probability: Outcome probability is a conditional probability of the failure outcome (release of the reservoir contents) given that a failure mode occurs. The likelihood of an outcome is dependent on the level of the system response. Values for the outcome probability are entered into Column (7) of the spreadsheet. The event probability, response probability, and the outcome probability for each failure mode were used in calculating the pathway probability for each failure mode.

D. Breach Peak Flow. Shown under Column (8) in the spreadsheet, the breach peak flow is the peak discharge related to the dam break occurring when the reservoir water surface is at the maximum (reservoir stage, Column (6)) for the loading being considered. The breach peak flow was used in determining economic damage which is presented in Section VIII - Damage Assessment.

E. Pathway Probability. Pathway probability, as shown in Column (9) of the spreadsheet, is the product of the event probability, the response probability, and the outcome probability. It was used in conjunction with the economic damage per event (Column (10)) to calculate the annual risk cost.

Economic Damage

A. Economic Damage per Event. Economic damage per event, expressed in millions of dollars per year, was presented in detail in Section VIII -Damage Assessment and is shown in Column (10) of the spreadsheet. The value of economic damage per event was determined by using the breach peak flow value shown in Column (8) and the damage outflow relationship developed in Section VIII.

B. Annual Risk Costs. Shown under Columns (11 through 14) are the annual risk costs associated with a specific system response under a given loading condition. The sum of annual risk costs is shown in Column (15) which represents the annual risk cost for the loading event shown in Column (1).

C. Total Annual Risk Cost. Annual risk costs for the hydrologic, seismic, and static events are added to obtain the total annual risk cost for the alternative being considered.

Threat to Life

To estimate the threat to life in the risk assessment, it was first necessary to identify the downstream reaches where the population would be threatened by the flooding, resulting from failure of the dam associated with each loading event. The number of people exposed to the risk was determined and the exposure probability for the population at risk was also estimated.

For this study, two river reaches were identified where population would be at risk to flooding in the event of a dam failure. These reaches, from Tongue River Dam to Birney and the reach below Birney through Miles City, are identified in Column (16). The number of people at risk was estimated to be 114 and 10,032 for reaches from the dam to Birney and below Birney, respectively, and entered in Column (17).

Exposure probabilities are shown in Column (18) on the spreadsheet.

The estimated loss of life per loading event, Column (19) of the spreadsheet, was calculated by multiplying the number of people at risk by the exposure probability.

Computational Procedures

As stated previously, the risk cost analysis was performed using the risk model. Total annual risk cost was computed for each alternative. Detailed descriptions of alternatives are presented in Section VII - Alternatives Considered.

The following parameters were required as inputs to the risk model: event type, event probability, response type, response probability, outcome type, reservoir stage, outcome probability, breach peak flow, economic damage per event, population at risk (location and number of people), and exposure probability.

The following estimates were computed within the Lotus 1-2-3 program: pathway probability, annual risk cost, and loss of life per event. The computations were made with the following equations:

- Pathway Probability = Event Probability x Response Probability x Outcome Probability
- Annual Risk Cost = Pathway Probability x Economic Damage Per Event
- Loss of Life Per Event = Exposure Probability x Population at Risk

Total Annual Risk Cost Per Event is the sum of Annual Risk Costs associated with all responses for the loading event being considered.

Annual risk cost for dam replacement was equal to the sum of the pathway probabilities multiplied by the replacement cost of the dam. The replacement cost for the dam was estimated by DNRC to be 150 million dollars.

The annual risk cost for an alternative is the sum of all annual risk costs associated with each individual loading event applicable to the alternative plus the annual risk cost for replacing the dam. This sum is shown at the end of the computation sheet for static events (Table IX-1D).

Results of Computation

As explained earlier, the tables used as examples for describing the Lotus 1-2-3 spreadsheets were the actual results for Alternative A. Risk costs and probability of life loss were also computed using the Lotus 1-2-3 spreadsheet risk model for Alternatives B, C, D, and E. Results of the computations for all five alternatives for annual risk cost and loss of life probabilities are summarized in Table IX-2 at the back of this section and detailed computations for each alternative are contained in Appendix B. The pathway probabilities for hydrologic, seismic, static, and all events combined are also equivalent to the loss-of-life probabilities for each category.

TABLE IX-1

Tongue River Dam Risk Analysis — ALTERNATIVE A, EXISTING DAM

LOADING		SYSTEM RESPONSE		OUTCOME					ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12) ANNUAL RISK COST ($*10**6)	(13) ANNUAL RISK COST ($*10**6)	(14) ANNUAL RISK COST ($*10**6)	(15) (TOTAL/ EVENT)	(16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
HYDROLOGIC - SPRING FLOOD (PEAK INFLOW IN K. CFS)																		
0-10	8.75E-01	NO FAIL (& PF)	1		3425.4	1		0.875										
[0-7]		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000	590	0.00E+00						0.000	DAM-BIRNEY	114	0.075000	8.5
									275.75	0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000	580	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									275.75		0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000	590	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									275.75			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	590	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									275.75				0.000		BELOW BIRNEY	10032	0.000200	2.0
10-15	1.80E-02	NO FAIL (& PF)	0.85		3427.2	1		0.0171										
[7-11]		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000	830	0.00E+00						0.251	DAM-BIRNEY	114	0.075000	8.5
									278.8	0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0500															
				F STILL B.		1.0000	830	9.00E-04							DAM-BIRNEY	114	0.075000	8.5
									278.8		0.251				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000	830	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									278.8			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	830	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									278.8				0.000		BELOW BIRNEY	10032	0.000200	2.0
15-20	4.00E-03	NO FAIL (& PF)	0.85		3428.8	1		0.0034										
[11-16]		SPILL CREST F	0.0500															
				F - SPILLWAY		1.0000	870	2.00E-04						0.168	DAM-BIRNEY	114	0.075000	8.5
									280.8	0.058					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.1000															
				F STILL B.		1.0000	870	4.00E-04							DAM-BIRNEY	114	0.075000	8.5
									280.8		0.112				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000	870	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									280.8			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	870	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									280.8				0.000		BELOW BIRNEY	10032	0.000200	2.0
20-25	8.00E-04	NO FAIL (& PF)	0.85		3430	1		0.00052										
[16-20]		SPILL CREST F	0.2000															
				F - SPILLWAY		1.0000	890	1.80E-04						0.079	DAM-BIRNEY	114	0.075000	8.5
									281.3	0.045					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.1500															
				F STILL B.		1.0000	890	1.20E-04							DAM-BIRNEY	114	0.075000	8.5
									281.3		0.034				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000	890	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									281.3			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	890	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									281.3				0.000		BELOW BIRNEY	10032	0.000200	2.0

LOADING		SYSTEM RESPONSE		OUTCOME					ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12) ANNUAL RISK COST ($*10**6)	(13) ANNUAL RISK COST ($*10**6)	(14) ANNUAL RISK COST ($*10**6)	(15) (TOTAL/ EVENT)	(16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
25-30	8.00E-04	NO FAIL (& PF)	0.45		3431	1		0.00038										
(20-24)		SPILL CREST F	0.3000															
				F - SPILLWAY		1.0000	710	2.40E-04						0.124	DAM-BIRNEY	114	0.075000	8.5
									282.5	0.068					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.2500															
				F STILL B.		1.0000	710	2.00E-04							DAM-BIRNEY	114	0.075000	8.5
									282.5		0.057				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000	710	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									282.5			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	710	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									282.5				0.000		BELOW BIRNEY	10032	0.000200	2.0
30-50	8.00E-04	NO FAIL (& PF)	0.15		3433.2	1		0.00012										
(24-42)		SPILL CREST F	0.4000															
				F - SPILLWAY		1.0000	880	3.20E-04						0.187	DAM-BIRNEY	114	0.075000	8.5
									289.5	0.083					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.4000															
				F STILL B.		1.0000	880	3.20E-04							DAM-BIRNEY	114	0.075000	8.5
									289.5		0.083				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0500															
				F SPILLWAY		1.0000	880	4.00E-05							DAM-BIRNEY	114	0.075000	8.5
									289.5			0.012			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	880	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									289.5				0.000		BELOW BIRNEY	10032	0.000200	2.0
50-80	3.00E-04	NO FAIL (& PF)	0		3437.3	1		0										
(42-68)		SPILL CREST F	0.4500															
				F - SPILLWAY		1.0000	1130	1.35E-04						0.088	DAM-BIRNEY	114	0.075000	8.5
									287	0.040					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.4500															
				F STILL B.		1.0000	1130	1.35E-04							DAM-BIRNEY	114	0.075000	8.5
									287		0.040				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.1000															
				F SPILLWAY		1.0000	1130	3.00E-05							DAM-BIRNEY	114	0.075000	8.5
									287			0.009			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	1130	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									287				0.000		BELOW BIRNEY	10032	0.000200	2.0
80-110	1.80E-04	NO FAIL (& PF)	0		3441.8	1		0										
(88-103)		SPILL CREST F	0.4500															
				F - SPILLWAY		1.0000	1380	8.10E-05						0.055	DAM-BIRNEY	114	0.075000	8.5
									303	0.026					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.4500															
				F STILL B.		1.0000	1380	8.10E-05							DAM-BIRNEY	114	0.075000	8.5
									303		0.025				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.1000															
				F SPILLWAY		1.0000	1390	1.80E-05							DAM-BIRNEY	114	0.075000	8.5
									303			0.005			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	1380	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									303				0.000		BELOW BIRNEY	10032	0.000200	2.0

LOADING		SYSTEM RESPONSE			OUTCOME				ECONOMIC DAMAGE						THREAT TO LIFE			
[1] EVENT TYPE	[2] EVENT PROB	[3] RESPONSE TYPE	[4] RESPONSE PROB	[5] OUTCOME TYPE	[6] RESERVOIR STAGE (FT MSL)	[7] OUTCOME PROB	[8] BREACH PEAK FLOW (K CFS)	[8] PATHWAY PROB.	[10] PER EVENT ($*10**6)	[11] ANNUAL RISK COST ($*10**6)	[12] ($*10**6)	[13] ($*10**6)	[14] ($*10**6)	[15] (TOTAL/ EVENT)	[16] POPULATION AT RISK	[17] POPULATION AT RISK	[18] EXPOSURE PROB	[19] LOSS OF LIFE PER EVENT
110-200 (103-198)	8.00E-05	NO FAIL (& PF)	0		3443.7	1		0										
		SPILL CREST F	0.4500	F - SPILLWAY		1.0000	1550	3.80E-05	308	0.011				0.025	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.4500	F STILL B.		1.0000	1560	3.80E-06	308		0.011				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.1000	F SPILLWAY		1.0000	1550	8.00E-06	398			0.003			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	1550	0.00E+00	308				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
200-382 (198-378)	3.00E-05	NO FAIL (& PF)	0		3444.7	1		0										
		SPILL CREST F	0.4500	F - SPILLWAY		1.0000	1880	1.35E-05	309.5	0.004				0.009	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.4500	F STILL B.		1.0000	1880	1.35E-05	309.6		0.004				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.1000	F SPILLWAY		1.0000	1680	3.00E-06	309.6			0.001			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	1880	0.00E+00	309.6				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
>382 (>378)	1.00E-05	NO FAIL (& PF)	0		3445.6	1		0										
		SPILL CREST F	0.4500	F - SPILLWAY		1.0000	1760	4.50E-06	311	0.001				0.003	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.4500	F STILL B.		1.0000	1750	4.60E-06	311		0.001				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.1000	F SPILLWAY		1.0000	1750	1.00E-06	311			0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	1760	0.00E+00	311				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
							TOTAL	3.50E-03	TOTAL =	0.343	0.827	0.030	0.000					

Annual Risk Cost (Spring Flood Event)= 1.001

TABLE IX-1B

Tongue River Dam Risk Analysis — ALTERNATIVE A, EXISTING DAM — Summer Flood Event, Sheet 1 of 3

LOADING		SYSTEM RESPONSE		OUTCOME					ECONOMIC DAMAGE						THREAT TO LIFE			
[1] EVENT TYPE	[2] EVENT PROB	[3] RESPONSE TYPE	[4] RESPONSE PROB	[5] OUTCOME TYPE	[6] RESERVOIR STAGE (FT MSL)	[7] OUTCOME PROB	[8] BREACH PEAK FLOW (K CFS)	[9] PATHWAY PROB.	[10] PER EVENT ($*10**6)	[11] ANNUAL RISK COST ($*10**6)	[12] ANNUAL RISK COST ($*10**6)	[13] ANNUAL RISK COST ($*10**6)	[14] ANNUAL RISK COST ($*10**6)	[15] (TOTAL/ EVENT)	[16] POPULATION AT RISK	[17] POPULATION AT RISK	[18] EXPOSURE PROB	[19] LOSS OF LIFE PER EVENT
HYDROLOGIC - SUMMER FLOOD (INFLOWS IN K. CFS)																		
0-10 [2]	0.99955	NO FAIL (& PF)	1		3424.4	1		0.99955										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000	580	0.00E+00						0.000	DAM-BIRNEY	114	0.075000	8.5
									273	0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000	580	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									273		0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000	580	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									273			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	580	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									273				0.000		BELOW BIRNEY	10032	0.000200	2.0
10-15 [4.5]	1.50E-04	NO FAIL (& PF)	0.87		3424.7	1		0.000145										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000	570	0.00E+00						0.001	DAM-BIRNEY	114	0.075000	8.5
									274	0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0300	F STILL B.		1.0000	570	4.50E-06							DAM-BIRNEY	114	0.075000	8.5
									274		0.001				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000	570	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									274			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	570	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									274				0.000		BELOW BIRNEY	10032	0.000200	2.0
15-20 [5]	1.00E-04	NO FAIL (& PF)	0.9		3425	1		0.00009										
		SPILL CREST F	0.0300	F - SPILLWAY		1.0000	575	3.00E-06						0.003	DAM-BIRNEY	114	0.075000	8.5
									274.5	0.001					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0700	F STILL B.		1.0000	575	7.00E-06							DAM-BIRNEY	114	0.075000	8.5
									274.5		0.002				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000	575	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									274.5			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	575	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									274.5				0.000		BELOW BIRNEY	10032	0.000200	2.0
20-25 [5.5]	8.00E-05	NO FAIL (& PF)	0.75		3425.4	1		0.00006										
		SPILL CREST F	0.1600	F - SPILLWAY		1.0000	585	1.28E-05						0.006	DAM-BIRNEY	114	0.075000	8.5
									275.37	0.004					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0900	F STILL B.		1.0000	585	7.20E-06							DAM-BIRNEY	114	0.075000	8.5
									275.37		0.002				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000	585	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									275.37			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	585	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									275.37				0.000		BELOW BIRNEY	10032	0.000200	2.0

LOADING		SYSTEM RESPONSE		OUTCOME					ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12) ($*10**6)	(13) ($*10**6)	(14) ($*10**6)	(15) (TOTAL/ EVENT)	(16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
25-30 (8.5)	4.00E-05	NO FAIL (& PF)	0.55		3425.8	1		0.000022										
		SPILL CREST F	0.2800															
				F - SPILLWAY		1.0000	585	1.12E-05						0.005	DAM-BIRNEY	114	0.075000	8.5
									278.12	0.003					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.1700															
				F STILL B.		1.0000	585	8.80E-08							DAM-BIRNEY	114	0.075000	8.5
									278.12		0.002				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000	585	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									278.12			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	585	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									278.12				0.000		BELOW BIRNEY	10032	0.000200	2.0
30-50 (8.5)	4.00E-05	NO FAIL (& PF)	0.2		3426.7	1		0.000008										
		SPILL CREST F	0.3800															
				F - SPILLWAY		1.0000	710	1.52E-05						0.009	DAM-BIRNEY	114	0.075000	8.5
									282.5	0.004					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.3800															
				F STILL B.		1.0000	710	1.52E-05							DAM-BIRNEY	114	0.075000	8.5
									282.5		0.004				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0400															
				F SPILLWAY		1.0000	710	1.60E-06							DAM-BIRNEY	114	0.075000	8.5
									282.5			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	710	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									282.5				0.000		BELOW BIRNEY	10032	0.000200	2.0
50-80 (8)	3.00E-05	NO FAIL (& PF)	0		3428.5	1		0										
		SPILL CREST F	0.4500															
				F - SPILLWAY		1.0000	845	1.35E-05						0.008	DAM-BIRNEY	114	0.075000	8.5
									288	0.004					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.4500															
				F STILL B.		1.0000	845	1.35E-05							DAM-BIRNEY	114	0.075000	8.5
									289		0.004				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.1000															
				F SPILLWAY		1.0000	845	3.00E-06							DAM-BIRNEY	114	0.075000	8.5
									288			0.001			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	845	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									288				0.000		BELOW BIRNEY	10032	0.000200	2.0
80-110 (16.5)	1.00E-05	NO FAIL (& PF)	0		3429.5	1		0										
		SPILL CREST F	0.4500															
				F - SPILLWAY		1.0000	945	4.50E-06						0.003	DAM-BIRNEY	114	0.075000	8.5
									282.1	0.001					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.4500															
				F STILL B.		1.0000	945	4.50E-06							DAM-BIRNEY	114	0.075000	8.5
									282.1		0.001				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.1000															
				F SPILLWAY		1.0000	945	1.00E-06							DAM-BIRNEY	114	0.075000	8.5
									292.1			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	945	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									292.1				0.000		BELOW BIRNEY	10032	0.000200	2.0

Tongue River Dam Risk Analysis — ALTERNATIVE A, EXISTING DAM

Summer Flood Event, Sheet 3 of 3

LOADING		SYSTEM RESPONSE			OUTCOME				ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12) ANNUAL RISK COST ($*10**6)	(13) ANNUAL RISK COST ($*10**6)	(14) ANNUAL RISK COST ($*10**6)	(15) (TOTAL/ EVENT)	(16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
110-200 (38.5)	8.00E-08	NO FAIL (& PF)	0		3433.7	1		0										
		SPILL CREST F	0.4500	F - SPILLWAY		1.0000	1115	2.70E-08	298.5	0.001				0.002	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.4500	F STILL B.		1.0000	1115	2.70E-08	298.5		0.001				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.1000	F SPILLWAY		1.0000	1115	8.00E-07	298.5			0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	1115	0.00E+00	298.5				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
200-382 (87)	3.00E-08	NO FAIL (& PF)	0		3439.8	1		0										
		SPILL CREST F	0.4500	F - SPILLWAY		1.0000	1215	1.35E-08	300	0.000				0.001	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.4500	F STILL B.		1.0000	1215	1.35E-08	300		0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.1000	F SPILLWAY		1.0000	1215	3.00E-07	300			0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	1215	0.00E+00	300				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
>382 (>122)	1.00E-08	NO FAIL (& PF)	0		3446.2	1		0										
		SPILL CREST F	0.4500	F - SPILLWAY		1.0000	1580	4.50E-07	308	0.000				0.000	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.4500	F STILL B.		1.0000	1580	4.50E-07	308		0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.1000	F SPILLWAY		1.0000	1580	1.00E-07	308			0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.8 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	1580	0.00E+00	308				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
							TOTAL	1.35E-04	TOTAL =	0.018	0.018	0.002	0.000					

Annual Risk Cost (Summer Flood Event) = 0.038

TABLE IX-1C

Tongue River Dam Risk Analysis — ALTERNATIVE A, EXISTING DAM — Seismic Event

LOADING		SYSTEM RESPONSE			OUTCOME				ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12)	(13)	(14)	(15)	(16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
SEISMIC - (MAGNITUDE)																		
M 0. - 6.5	1.00E-02	NO FAIL (& PF)	1		3424.4	1		0.01		0								
(0 -.08g)		RES. LANDSLIDE	0															
				F - BREACH		0.0000	580	0.00E+00							DAM - BIRNEY	114	0.150000	17.1
									273	0					BELOW BIRNEY	10032	0.000200	2.0
		FOUNDAT LIQ	0.0000															
				F - BREACH		0.0000	580	0.00E+00							DAM - BIRNEY	114	0.150000	17.1
									273	0					BELOW BIRNEY	10032	0.000200	2.0
		EMB. DEFOR.	0.0000															
				F - BREACH		0.0000	580	0.00E+00							DAM - BIRNEY	114	0.150000	17.1
									273	0					BELOW BIRNEY	10032	0.000200	2.0
		CORE CRACK/PIPE	0.0000															
				F - BREACH		0.1000	580	0.00E+00							DAM - BIRNEY	114	0.150000	17.1
									273	0					BELOW BIRNEY	10032	0.000200	2.0
		OUTLET-RUPTURE	0.0000															
				F - BREACH		0.2500	580	0.00E+00							DAM - BIRNEY	114	0.150000	17.1
									273	0					BELOW BIRNEY	10032	0.000200	2.0
M>6.5	1.00E-03	NO FAIL (& PF)	0.898			1		0.000898		0								
(>.08g)		RES. LANDSLIDE	0.001															
				F - BREACH		0.0000	580	0.00E+00							DAM - BIRNEY	114	0.150000	17.1
									273	0					BELOW BIRNEY	10032	0.000200	2.0
		FOUNDAT LIQ	0.0010															
				F - BREACH		0.0010	580	1.00E-09							DAM - BIRNEY	114	0.150000	17.1
									273	0					BELOW BIRNEY	10032	0.000200	2.0
		EMB. DEFOR.	0.0000															
				F - BREACH		0.0000	580	0.00E+00							DAM - BIRNEY	114	0.150000	17.1
									273	0					BELOW BIRNEY	10032	0.000200	2.0
		CORE CRACK/PIPE	0.0000															
				F - BREACH		0.0000	580	0.00E+00							DAM - BIRNEY	114	0.150000	17.1
									273	0					BELOW BIRNEY	10032	0.000200	2.0
		OUTLET-RUPTURE	0.0000															
				F - BREACH		0.0000	580	0.00E+00							DAM - BIRNEY	114	0.150000	17.1
									273	0						10032	0.000200	2.0
							TOTAL	1.00E-09	TOTAL	0.000000								

Annual Risk Cost (Seismic Event)= 0.000000

TABLE IX-1D

Tongue River Dam Risk Analysis — ALTERNATIVE A, EXISTING DAM — Static Events

LOADING		SYSTEM RESPONSE		OUTCOME					ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12)	(13)	(14)	(15)	(16) POPULATION AT RISK	(17) EXPOSURE PROB	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
STATIC - FOUNDATION																		
	1.00E+00	EMB. DEFOR.	3.80E-05	F - BREACH	3424.4	1.0000	580	3.80E-05		0.000					DAM - BIRNEY	114	0.150000	17.1
									273	0.010					BELOW BIRNEY	10032	0.000200	2.0
									TOTAL =	0.010								
STATIC - PIPING EMBANKMENT																		
	1.00E+00	PIPING	1.20E-05	F - BREACH		1.0000	580	1.20E-05		0.000					DAM - BIRNEY	114	0.150000	17.1
									273	0.003					BELOW BIRNEY	10032	0.000200	2.0
									TOTAL =	0.003								
STATIC - SLOPE STABILITY																		
	1.00E+00	EMB. DEFOR.	2.80E-06	F - BREACH		1.0000	580	2.80E-06		0.000					DAM - BIRNEY	114	0.150000	17.1
									273	0.001					BELOW BIRNEY	10032	0.000200	2.0
									TOTAL =	0.001								
STATIC - PIPING OUTLET WORKS																		
	1.00E+00	PIPING/GATE F	1.80E-06	F - BREACH		1.0000	580	1.80E-06		0.000					DAM - BIRNEY	114	0.150000	17.1
									273	0.000					BELOW BIRNEY	10032	0.000200	2.0
									TOTAL =	0.000								
STATIC - LANDSLIDE INTO RESERVOIR																		
	1.00E-02	SEICHE	1.00E-03			1.0000									DAM - BIRNEY	114	0.150000	17.1
				F-BREACH		0.0000	580	0.00E+00	273	0.000					BELOW BIRNEY	10032	0.000200	2.0
							TOTAL	5.24E-05	TOTAL =	0.000								

Annual Risk Cost (Static Event)= 0.014306

ANNUAL RISK COST FOR LOADING EVENTS = 1.053
ANNUAL RISK COST FOR DAM REPLACEMENT = 0.553

ANNUAL RISK COST FOR ALTERNATIVE = 1.606 Million $

TABLE IX-2

RISK ANALYSIS SUMMARY
(Cost in Million $)

Loading Event/System Response	Alternative A Pathway Prob.	Alternative A Annual Risk Cost	Alternative B Pathway Prob.	Alternative B Annual Risk Cost	Alternative C Pathway Prob.	Alternative C Annual Risk Cost	Alternative D Pathway Prob.	Alternative D Annual Risk Cost	Alternative E Pathway Prob.	Alternative E Annual Risk Cost
I. Hydrologic										
A. Spring Flood	3.50E-03		3.00E-06		8.75E-05		1.79E-04			
1. Spillway Crest		0.343		0.000		0.000		0.091		
2. Tailrace Erosion		0.628		0.000		0.000		0.011		
3. Piping Clinker		0.030		0.001		0.007		0.006		
4. Overtopping		0.000		0.000		0.021		0.017		
Sub-Total		1.001		0.001		0.028		0.125		
B. Summer Flood	1.35E-04		3.00E-07		7.35E-06		1.43E-05			
1. Spillway Crest		0.018		0.000		0.000		0.001		
2. Tailrace Erosion		0.018		0.000		0.000		0.001		
3. Piping Clinker		0.002		0.000		0.000		0.000		
4. Overtopping		0.000		0.000		0.002		0.001		
Sub-Total		0.038		0.000		0.002		0.003		
II. Seismic	1.00E-06	0.000	1.00E-06	0.000	1.00E-06	0.000	1.00E-06	0.000		
III. Static	5.24E-05	0.014	5.24E-05	0.014	5.24E-05	0.014	5.24E-05	0.014		
TOTAL PROBABILITY	3.63E-03		5.67E-05		1.48E-04		2.47E-04			
ANNUAL RISK COST (Due to Dam Failure)		1.053		0.016		0.044		0.143		
ANNUAL RISK COST (Due to Dam Replacement)		0.553		0.009		0.022		0.037		
ANNUAL RISK COST (Due to Natural Flood Dam Removed)		0.296		0.296		0.296		0.296		0.296
TOTAL ANNUAL RISK COST		1.902		0.321		0.362		0.476		0.296

NOTE: The flood-frequency curves (Figures V-1 and V-2) for flood events and the intermediate estimate curve (Figure VIII-1) for damage assessment were used in the computation of the results presented in this table.

X. DISCUSSION

A. Background

The economic evaluations made of Alternatives A through E were based on the recommendations and procedures set forth in the Water Resources Council Principles and Guidelines for Water Resource Planning and in the Bureau of Reclamation's Technical Memorandum No. 7 Guidelines to Decision Analysis. Alternative A is the dam failure case, "Existing Dam," to which each modification alternative (B, C, D, and E) was compared. The estimated annualized risk cost of each modification alternative is deducted from the estimated risk cost associated with dam failure-Existing Dam (Alternative A) to obtain an estimate of reduced risk cost which is the estimated benefit induced by each modification alternative. Total annual cost (annual risk cost plus annualized construction cost) and the benefit to cost (B/C) ratios were computed for each alternative. The B/C ratios were compared to characterize the economic efficiency of the alternatives. In addition, the economic evaluation compares the reduction of expected damages with the cost of achieving the reduction offered by each risk modification alternative. The annual risk costs due to natural flows were computed to be $296,000 (Table IX-2). The natural flow risk costs were computed because there is no flood control designated in the project and, therefore, it was necessary to quantify and isolate the fixed costs allocated to the natural flows.

B. Alternative A - Existing Dam

There were significant incremental damages due to dam failure for Alternative A - Existing Dam. The annual risk cost was $1,610,000, there were no construction costs, and the total annual cost for Alternative A was $1,610,000. Other considerations regarding this alternative were that the potential for loss of life is highest of all studied alternatives, the structure would not meet current federal dam safety guidelines, and the dam is estimated to safely pass only approximately 5% of the current PMF.

C. Alternative B - Spillway Capacity 382,000 cfs (100% PMF)

The incremental damages due to Alternative B - Spillway Capacity 382,000 cfs (100% PMF) were relatively low compared to Alternative A (Existing Dam). The annual risk cost was $25,000, the construction costs were estimated at approximately $115,000,000 or $10,300,000 on an annualized basis. The total annual cost (annual risk cost plus annualized construction cost) for Alternative B was $10,325,000. Alternative B is estimated to reduce the annual risk cost by $1,580,000 compared to Alternative A which yielded a benefit to cost ratio of 0.15 (reduction in annual risk compared to Alternative A is defined as the benefit). Other considerations were that the potential for loss of life is lowest for this alternative, the structure would meet current federal guidelines for dam safety, and the dam would be designed to safely pass 100% of the PMF.

D. Alternative C - Spillway Capacity 103,400 cfs (27% PMF)

Alternative C also produced a significant reduction of incremental damages compared to Alternative A. The annual risk cost of Alternative C was $70,000 and the construction costs were estimated at $51,000,000 with an annualized construction cost of $4,580,000. The total annual cost for Alternative C was $4,650,000. This alternative reduced the annual risk costs by $1,540,000 as compared to Alternative A, and the benefit to cost ratio was 0.34. Other considerations were that the potential for loss of life is reduced compared to Alternative A; the structure would not meet current federal dam safety guidelines, but the dam would be designed to safely pass approximately 27% of the current PMF.

E. Alternative D - Spillway Capacity 60,000 cfs (16% PMF)

Alternative D also produced significant reductions of incremental damages compared to Alternative A. The annual risk cost of Alternative D was estimated at $180,000, the construction costs were estimated at $21,000,000 with an annualized construction cost of $1,920,000 and the total annual cost for Alternative D was $2,100,000. This alternative reduced the annual risk costs by $1,430,000 as compared to Alternative A, and the benefit to cost ratio was 0.74. Other considerations were that the potential for loss of life is reduced compared to Alternative A; the structure would not meet current federal dam safety guidelines, but the dam would be designed to safely pass approximately 16% of the current PMF.

F. Alternative E - Breach

Alternative E eliminated all risk costs due to dam failure for the largest reduction of incremental damages compared to Alternative A. The annual risk cost for Alternative E was zero, the construction costs were estimated at $20,000,000 with an annualized construction cost of $1,800,000, and, therefore, the total annual cost for Alternative E was $1,800,000. This alternative reduced the annual risk costs by $1,610,000, and had a benefit to cost ratio of 0.89 as compared to Alternative A. An important consideration was that the potential for loss of life due to dam failure is eliminated. There would be, however, a potential for loss of life due to natural flooding that remains. Another important aspect to consider would be that the public acceptance of breaching the dam, with accompanying loss of benefits versus elimination of the risk, would be difficult to assess.

A comparison of the alternatives is presented in Table X-1 and a summary of the costs, benefits, and benefit to cost ratios is presented in Table X-2.

TABLE X-1

COMPARISON OF ALTERNATIVES

	A	B	C	D	E
Construction Costs	0	$115,000,000	$51,000,000	$21,000,000	$20,000,000
Annualized Construction Costs	0	$ 10,300,000	$ 4,580,000	$ 1,920,000	$ 1,800,000
Flood Protection Level (percentage of PMF)	5	100	27	16	0
Annual Net Risk Costs	$1,610,000	$25,000	$70,000	$180,000	$0
Chance for Loss of Life	1 in 270	1 in 17,600	1 in 6,800	1 in 4,000	
Other Considerations	Does not meet Federal Dam Safety Guidelines High probability of of dam failure	New project with new benefits generated Meets Federal Dam Safety Guidelines Potential benefits to settle Indian water rights	Does not meet Federal Dam Safety Guidelines	Does not meet Federal Dam Safety Guidelines	Difficult to assess public acceptance of loss of project versus elimination of all risk due to dam failure Potential legal claims for damages and breach of contract and political controversy Loss of protection from low frequency flood

TABLE X-2

Summary of Costs, Benefits, and B/C Ratios for Alternatives

Alternatives	Inflow Design Capacity (cfs)	Construction Costs (millions)	Annualized Construction Cost (millions)	Annual Risk Cost (millions)	Benefits	Total Annual Cost (millions)	Benefit to Cost Ratio (B/C)
Alternative A (Existing Dam)	20,000	0	0	$ 1.610	N/A	1.610	N/A
Alternative B	382,000 (PMF)	115.0	10.30	.025	1.580	10.30	.15
Alternative C	103,400	51.0	4.58	.070	1.540	4.65	.34
Alternative D	60,000	21.0	1.92	.180	1.430	2.10	.74
Alternative E (Breach the Dam)	-	20.0	1.80	0	1.610	1.80	.89

N/A - Not applicable because Alternative A is reference alternative.

NOTE: The total costs for construction must be equal to or less than approximately $18,000,000 to yield a B/C ratio of 1.0 or greater.

G. Uncertainty Analysis

To ascertain the impact of the uncertainties involved in the risk assessment on the conclusions of the risk assessment, sensitivity analyses were made for some of the probability and consequence estimates. The areas of uncertainty within the risk assessment included: the return period chosen for the PMF, the system response probability estimates, the dam break flood routings, the damage assessments, and the threat to life estimates. From among these five areas of uncertainty, the following three were chosen on which to perform sensitivity analyses: the return period or annual frequency of occurrence of the PMF, the damage assessments, and system response probabilities. Before discussing the sensitivity analyses made on these three selected areas, some brief comments concerning dam break flood routings and threat to life are in order.

The dam break flood routings were not included because the sensitivity of downstream flooding to variations in dam breach parameters was done as part of the flood inundation mapping studies reported in Section VIII-B, Inundation Studies. These parametric studies showed that downstream inundation was most sensitive to

variations in the breach development time (time to breach of 2.0 hours was used). Although inundation maps were not developed for a range of breach parameters, relatively conservative values were used in order to yield conservative estimates of areas expected to be flooded.

The threat to life estimates were also not included in the formal sensitivity analysis because a quick examination revealed that there would be an almost infinite number of combinations of input parameters that could be studied. Instead, a cursory evaluation was made by inspection. That evaluation indicated that the overall threat to life would not change significantly even with slight variations in the pathway probabilities which are a function of the event probabilities, the conditional response probabilities, and the conditional outcome probabilities. There were two parameters that apparently could have, given a large variation in their magnitude, affected the threat to life significantly; the estimated PAR, population at risk, and the exposure probability, which is a function of warning time received by people in the event of a flood. Fortunately, the DNRC has an established warning system connected with the Tongue River Dam which is regularly tested. This fact alone eliminated a large part of the uncertainty that could have been associated with the exposure probability parameters.

Returning now to the three areas for which sensitivity studies were made, the first to be discussed is return period of the PMF. The risk model for each of the five alternatives, A through E, was rerun for an order of magnitude of one lower return period of the PMF (1×10^6) and an order of magnitude of one higher return period (1×10^4) than was used for the basic risk assessment (1×10^5). The effect of this variation in return period of the PMF on the downstream damages was tabulated for each alternative and compared to the damage estimates determined from the risk assessment. The tabulated results are shown in Table X-3.

TABLE X-3

SENSITIVITY STUDY RESULTS
BASED ON TOTAL COSTS

REGRET MATRICES

Alternative	PMF Return Period (Years) 10^4	Rank	10^5	Rank	10^6	Rank
A	$ 0.000	1	$ 0.000	1	$ 5.808	4
B	9.735	5	8.718	5	8.536	5
C	4.024	4	3.040	4	3.128	3
D	1.406	3	0.494	3	1.175	2
E	1.212	2	0.194	2	0.000	1
Minimum Cost	$ 0.588		$ 1.606		$ 1.800	

Alternative	Economic Damages Low	Rank	Intermediate	Rank	High	Rank
A	$ 0.000	1	$ 0.000	1	$ 0.094	2
B	9.040	5	8.718	5	8.524	5
C	3.353	4	3.040	4	2.854	4
D	0.776	3	0.494	3	0.340	3
E	0.516	2	0.194	2	0.000	1
Minimum Cost	$ 1.284		$ 1.606		$ 1.800	

Alternative	Response Probability Low	Rank	Medium	Rank	High	Rank
A	$ 0.000	1	$ 0.000	1	$ 0.698	3
B	9.561	5	8.718	5	8.526	5
C	3.855	4	3.040	4	2.905	4
D	1.306	3	0.494	3	0.365	2
E	1.038	2	0.194	2	0.000	1
Minimum Cost	$ 0.762		$ 1.606		$ 1.800	

NOTE: All values in millions of dollars.

The sensitivity study results in Table X-3 are called regret matrices. The regret matrix is formed by determining the minimum value in each column and subtracting it from all the other entries in that column. The result, of course, is zero for the alternative with the minimum cost. The importance of this operation, however, is that each of the other values becomes ranked in comparison to the

others relative to the minimum cost alternative. The remaining value for each alternative is a relative measure, in monetary terms, of the "regret" or additional annual costs one would have for selecting a particular alternative instead of the least cost alternative.

The purpose for displaying the sensitivity results in this fashion was to determine the effects of varying the return period of the PMF on the overall ranking of the alternatives.

The first observation is that the minimum cost increases as the return period decreases. This is because the size of flood associated with a longer return period is larger and, consequently, the damages would be larger.

The second observation is that Alternative E has the least regret among all the alternatives compared to A in the middle column and Alternative D has the second smallest regret. The conclusion would be that Alternative D is the best given the constraint that the project is not to be abandoned. Without the constraint, Alternative E appears to be best in monetary terms.

The third observation is that the ranking among all alternatives remains constant for a PMF return period of 1×10^4 and changes slightly for a PMF return period of 1×10^6. For the longer return period, Alternative E becomes the least cost and Alternative D has the least regret. From this exercise, it was demonstrated that the conclusion about Alternative D being the least cost from among those alternatives that reduce the risks of the existing dam yet preserves the project was insensitive to the PMF return period over the range of return periods evaluated.

The second area of uncertainty addressed in the sensitivity studies was the economic damages. The risk assessment was made using the intermediate curve shown in Figure VIII-4. The purpose of the sensitivity study was to determine what affect varying the damage curve from low to high would have on the results of the risk assessment. Once again, the risk model was rerun for each alternative using the low and high damage curves and the results were tabulated in Table X-3 as was done for the studies to test sensitivity for PMF return period.

The overall minimum cost showed much less sensitivity to variations in the damage parameters than was evident with the PMF frequency parameters. This is an indication that estimating damages due to a flood based on historic data is a more deterministic activity with less uncertainty than attempting to predict probable maximum floods over thousands of years into the future with only a relatively brief historical data base (less than 100 years of record).

The rank of Alternative D to the other alternatives remained the same economically and showed no sensitivity to damage function for the range of curves examined.

The third area of uncertainty for which sensitivity studies were performed was system response probabilities. These probabilities were developed based on the engineering experience and judgement of the DNRC staff, its consultant and the PRC project team. Whenever engineers are asked to give estimates on the probability that a structure will respond in a particular manner, there is uncertainty. To test the effects that variations in the system response probabilities could have on the results of the risk assessment, the risk model was rerun with the system response probabilities shifted by one position upward and downward from that shown on the spreadsheets for each alternative.

The results are shown in Table X-3 using the regret matrix format. Although there is a larger overall deviation in the minimum cost than shown for the damage function parameters, the medium value is skewed toward the higher value which is a reflection of the conservatism used by all the individuals who made response probability estimates. The conclusions drawn regarding the relative ranking of all alternatives and more specifically the ranking of Alternative D relative to the other alternatives were the same for the response probability parameter as for the other two parameters evaluated previously.

H. Comparison to Other Risks

Modern society is complex and virtually every activity undertaken carries with it consequences or risks that are unknown, or at best uncertain. A partial list of

annual deaths in the United States by causes are shown in Table X-4. The number of deaths annually attributable to dam failures are also shown for dam failures before 1960 and since 1978 for comparison.

Part of the reason for conducting a risk assessment for the Tongue River Dam was to reduce the uncertainty of risk to life downstream in the event of dam failure. Results from the risk assessment did provide quantitative estimates of the probability of life loss for several types of loading conditions and system responses of the dam and its appurtenances. Those have been summarized in Section IX and are shown in detail for each alternative in the computer output spreadsheets contained in Appendix B.

In spite of a greatly clarified picture of the level of risk to life, however, the decision process for determining an acceptable level of risk to life remains a difficult one for the DNRC and the Montana Legislature.

Various approaches are available for determining the acceptable level of risk of life loss. Experience shows that no single criterion for determining acceptable risk is necessarily suitable for all situations. However, it is useful for decision makers to have available clearly presented comparisons between the risks associated with dam failure and those associated with other involuntary activities and public works projects in particular. Such comparisons can be made in terms of probability of life loss or in terms of the cost to save a life. For this purpose, the probability of life loss can be based on (1) actual failure rates for similar projects (revealed preference), (2) a consensus of what people consider to be acceptable (expressed preference), or (3) current regulatory and legal criteria (implied preference), which Rowe (1979) argues is a balance between what people want and what society can afford.

Using the approach described in three above, data were compiled from current data sources to show examples of cost-per-life-saved criteria in other public works and regulatory areas as shown in Table X-4. The cost-per-life-saved was computed for Alternatives B through E and are also shown for comparison.

TABLE X-4
COMPARISON OF RISKS

Value	Risk
1/5,000 Years = 0.0002	Risk of Dam Failure (Involuntary)*
1 in 4,000 = .00025	Risk of Death from Auto Accident in the United States (Voluntary)*

SOURCE: Comment on Societal Risk - David Okrent - April 1980.

Energy Risk Management, G.T. Goodman & W.D. Rowe, 1979.
*Voluntary and involuntary risk values should not be compared directly.

Annual Deaths in the United States by Causes
(USBR 1983 Workshop Handout)

Causes	Number of Deaths
All Causes	1,900,000
Health Related	
Heart and Artery Diseases	800,000
Cancer	400,000
Smoking	346,000
Result of Alcohol	205,000
Stroke	170,000
Crime Related	
Violence (Homicide and Suicide)	48,000
Child Abuse	5,000
All Accidents	106,000
Motor Vehicles (Alcohol related 26,000)	52,000
Falls	14,000
Fires	6,200
Drowning	5,800
Water Transport Accidents	1,500
Flash Floods	200
Lightning	150
Tornadoes	120
Others	26,030
Dam Failure (Before 1960)	15
Dam Failure (Since 1978)	2

Examples of Cost-Per-Life-Saved Criteria

Agency or Regulatory Discipline	$ \$ X 10^6 $/Life Saved
Nuclear Power Plant Design Features[2]	
Radwaste Effluent Treatment Systems	10
Containment	4
Occupational Health and Safety[1]	
OSHA[3] Coke Fume Regulations	4.5
OSHA Benzene Regulations	300
Environmental Protection[1]	
EPA[4] Vinyl Chloride Regulations	4
Automotive and Highway Safety[1]	
Seat Belts	0.08
TONGUE RIVER DAM ALTERNATIVE B	96.0
TONGUE RIVER DAM ALTERNATIVE C	34.0
TONGUE RIVER DAM ALTERNATIVE D	5.4
TONGUE RIVER DAM ALTERNATIVE E	2.1

1. From N.J. McCormick, "Reliability and Risk Analysis", 1981.
2. From E.P. O'Donnell and J.J. Mauro, "Nuclear Safety", 1979.
3. OSHA, Occupational Safety and Health Administration.
4. EPA, Environmental Protection Agency.

The computations for cost-per-life-saved for Alternatives B, C, D and E were made using the following equation:

$$CPLS_{Alt} = \frac{ACC_{Alt} - B_{Alt}}{PF_A \times L_A - PF_{Alt} \times L_{Alt}}$$

where

CPLS	=	Cost-Per-Life-Saved
Alt	=	Alternative Rehabilitation Action
A	=	Alernative A - Existing Dam
ACC	=	Annual Construction Cost
B	=	Annual Benefits
PF	=	Annual Probability of Failure
L	=	Estimated Number of Lives Lost

A graphical comparison is shown in Figure X-1.

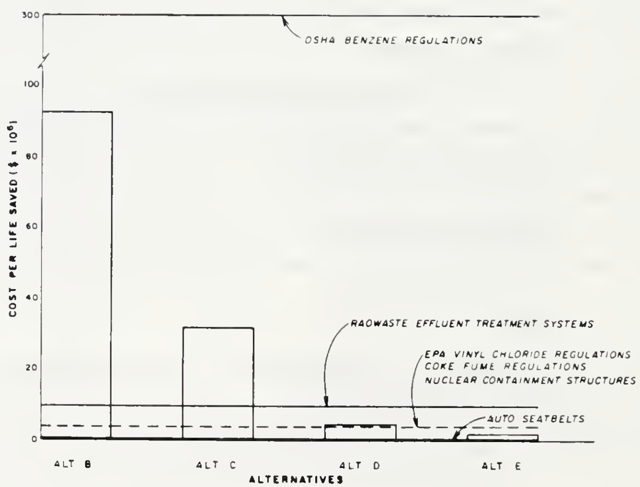


FIGURE X-1 COST-PER-LIFE-SAVED (CPLS) FOR ALTERNATIVES COMPARED WITH SOME SELECTED CPLS FIGURES FROM OTHER PUBLIC SAFETY AREAS

XI. CONCLUSIONS

1. Because the Probable Maximum Precipitation (PMP) values developed using Hydrometeorologial Report No. 55 (HMR 55) fall within the confidence bands shown in Harza's study, the Probable Maximum Flood (PMF) developed by Harza was considered acceptable and was used in this report.

Spring PMF:	
Peak Discharge	382,000 $ft.^3/s$
15-Day Volume	1,360,000 acre-feet
Summer PMF:	
Peak Discharge	108,000 $ft.^3/s$
40-Hour Volume	91,000 acre-feet

2. The largest net risk costs and probability of failure of the existing dam are related to hydrologic loading conditions.

3. The largest net risk costs and probability of failure of the existing dam would most likely occur due to progressive failure of the spillway and stilling basin (tailrace).

4. The five alternative project configurations assessed for risk and least cost in this study were selected jointly by DNRC staff and PRC from work performed previously by the Bureau of Reclamation and Harlan Miller Tait Associates.

   The alternatives investigated in this assessment included:

   A. Existing dam structure with no structural modifications and present reservoir operating restrictions removed - "Existing Dam."

   B. Modify the dam and spillway to safely pass the PMF and increase reservoir storage - "Spillway Capacity - 382,000 cfs (100% PMF)."

C. Modify the dam and spillway to pass a 103,400 cfs flood - "Spillway Capacity -103,400 (27% PMF)."

D. Modify the spillway and energy dissipator to pass a design capacity of 60,000 cfs (the original intended design capacity at a water surface of El. 3437.4 based on original construction drawing No. 9 - GR dated March 14, 1938) - "Spillway Capacity - 60,000 (16% PMF)."

E. Breaching the dam and restoration of the reservoir area - "Breach."

5. Updating the Emergency Action Plan regularly and maintaining and testing the emergency warning system periodically provides the greatest protection and beneficial reduction in the risk of life loss due to flooding from dam failure.

6. Alternative A - "Existing Dam," has the least total annual cost (sum of annual risk cost and annualized construction cost) among all the alternatives, but has the highest annual risk cost and represents the largest risk to property downstream and to lives (annual probability of life loss estimated to be 1 chance in 270.

7. Alternative B - "Spillway Capacity 382,000 (100% PMF)" had the largest total annual cost among all the alternatives but had one of the smallest risks to downstream property damage and life loss (annual probability of life loss estimated to be 1 chance in 17,600).

8. Alternative C - "Spillway Capacity 103,400 (25% PMF)" had the second highest total annual cost among all the alternatives and had a small risk to property and life (annual probability of life loss estimated to be 1 in 6,800).

9. Alternative D - "Spillway Capacity 60,000 (16% PMF)" produces the second largest reduction in annual risk costs for the least total annual cost compared to the existing dam from among all the alternatives and had a significant reduction in the risk to property and life downstream (probability of life loss estimated to be 1 in 4,000).

10. Alternative E - "Breach" was the only alternative which reduced the annual risk cost to zero; but at a total annual cost exceeding that of Alternative A - "Existing Dam" and all project benefits would be lost. The risk to life downstream due to dam failure would be reduced to zero.

11. Based on results from the uncertainty analysis which included sensitivity analyses of the flood frequencies, system responses and damage estimates, Alternative D remained the top ranked among all alternatives compared to the existing dam in maximum reduction in annual risk cost for least total annual cost, with the exception of Alternative E. This observation is a function of costs only and does not include life loss considerations (see conclusion 12).

12. The ranking of all alternatives on the basis of downstream risk to life from highest to lowest risk was Alternatives A, D, C, B, E. Although Alternative D is ranked second highest to the existing dam, Alternative A, it is evident based on Figure I-5 that the risk to life is significantly reduced between Alternative A and all the others. Therefore, Alternative D compares favorably with Alternatives B, C and E in effectively reducing the probability of life loss downstream.

13. The conclusions reached in the study and contained in this section were all predicated on the assumption that legally the State of Montana would not be liable for punitive damages and economically the state's liability would be limited to the incremental damages greater than those attributable to natural flood flow that would occur without the Tongue River Dam. Any changes in the legal environment which deviate from those assumed could significantly alter the conclusions and the viability of the risk assessment approach followed. A legal opinion by DNRC legal counsel addressing this subject is contained in Appendix A.

APPENDIX A

DNRC INTERNAL MEMORANDUM

TONGUE RIVER DAM LIABILITY

DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION

TED SCHWINDEN, GOVERNOR — 1520 EAST SIXTH AVENUE

STATE OF MONTANA

DIRECTOR'S OFFICE (406) 444-6699 — HELENA, MONTANA 59620

MEMORANDUM — November 3, 1986

TO: Sarah Bond
Counsel

FROM: Rick Bondy — Rick
Chief, Engineering Bureau

RE: Tongue River Risk Analysis.

In our work on the Tongue River Risk Analysis two legal questions have come up that have an impact on the Analysis.

1) What is the extent of a dam owner's liability for damages that would have occurred due a large flood even if the dam had not been there. For example, assume that a dam fails when the inflow to the project is 30,000 cfs. Subsequent to the dam failure the inflow continues to increase and finally peaks at 100,000 cfs. The failure of the dam causes a 200,000 cfs flow downstream of the dam. I can think of three potential levels of liability and I would like your opinion on which one we'd be most likely to be paying.

a) the owner of the dam could be liable for all the damages caused by the 200,000 cfs wave released by the failure of the dam
b) the dam owner could only be liable for the damages caused by the 200,000 cfs less damages that would have been caused by the 100,000 inflow,
c) the dam owner could be responsible for damages caused by the 200,000 cfs flood less whatever damages had already occurred at the time the dam failed.

I would also appreciate your assessment of the likelyhood that any punative damages might have to be paid, assuming it was known for several years prior to the failure that the dam was unsafe.

2) Based on preliminary results it appears that the cheapest thing to do for the Tongue River Project might be some combination of an acceptance of the risks and a repair of the dam that would not come close to meeting today's dam safety standards. It seems to me that if the owner could afford to take such a risk it may be appropriate to allow him to do so whereas, if failure of a structure would cause damages for which an owner could not afford to compensate he probably should not

be allowed to maintain such a structure. What I need to know here, though, is what do you understand the law to say on this subject. I would appreciate discussion here on life loss. Would the answer be different if we could develop a warning system that would probably warn people of the impending flood? Such a system could not be perfect, but we could build a pretty good one for a lot less than it costs to reconstruct the dam, I suspect.

I would appreciate a written response to these questions by November 12, 1986, if possible.

DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION

TED SCHWINDEN, GOVERNOR

1520 EAST SIXTH AVENUE

STATE OF MONTANA

DIRECTOR'S OFFICE (406) 444-6699

HELENA, MONTANA 59620

MEMORANDUM:

TO: Rick Bondy
Chief, Engineering Bureau

FROM: Sarah A. Bond
Legal Counsel

RE: Tongue River Dam Liability

DATE: December 22, 1986

By memo of November 3, 1986, you have requested opinion on three related questions.

1. Your first question presents several components.

   a. The State, as well as any private entity, is liable for damages occasioned by its negligence.

   b. If the State is found negligent in the operation, maintenance or design of the dam, it will be liable for resultant damages up to $750,000 for each claim and 1.5 million for each occurrence.[1] The burden of proving proximate cause and amount of damages is on the plaintiff but difficulty in segregating damages caused by negligence, and damages which would have occurred regardless thereof, does not prevent recovery for a jury's best estimate. Damages awarded against a government employee will be paid for by the state. § 2-9-305, MCA, (1985).

[1] Claim means all damages occurring to an individual.

c. The calculation of damages is extremely fact specific. The State's liability would be calculated on the basis of the damage caused by the failure, excepting only so much as could be shown would have occurred even if the dam hadn't failed, or, if the dam hadn't been there. It is unlikely that a mere subtraction of inflows and outflows would reflect the amount of damages proximately caused by the negligent failure.

d. Under current law, the State may not be held liable for punitive damages.

e. Independent contractors are not subject to these limitations, and currently not subject to any limitation on either compensatory or punitive damages.

2. a. Your second question involves moral issues not fully answered by the law. That is, should the State assume the risk based on a <u>financial</u> projection that some of its citizens should die? That is, because the State is not liable for punitive damages, no financial liability could attach because of outrageous or morally bankrupt behavior by the State. Monetary liability would attach for the actual amount of damages caused. Financial feasibility is not a defense to negligence.

b. Criminal liability theoretically could attach for violation by the dam safety act. Each day of a continuing violation is a misdemeanor. Theoretically, the State (in this case, the Director of the Department) could be convicted of homicide if its negligence caused a death. § 85-15-501, MCA, (1985). This section has never been construed. The governmental indemnity does not apply to malicious or criminal behavior.

<u>DISCUSSION</u>

1. <u>General Caveat</u>

Tort reform is among the legislative issues to be addressed at the 1987 legislative session. Hence, opinion on the law as it is now is likely to be rendered moot, in some respects, in the

near future. Damages are a substantive issue and the law in effect on the date of injury is the applicable law. Dvorak v. Huntley Project Irrigation District, 196 Mont. 167, 639 P.2d 62 (1981); Jacques v. Montana National Guard, 199 Mont. 493, 649 P.2d 1319 (1982). Although the legislature has always been empowered to establish liability limits,[2] the Montana Supreme Court most recently in White, and Pfoft, has held the right to receive redress for legal injury is a fundamental constitutional right and therefore legislative limitations thereon are subject to the "strict scrutiny" test. Art. II, § 16, Mont. Const. Constitional Initiative (CI) 30 seems to clear the way for stricter limits by amending the constitution as follows: (words stricken are deleted, those underlined are added).

Section 16. The administration of justice (1) Courts of Justice shall be open to every person, and speedy remedy afforded for every injury of person or property or character. Right and justice shall be administered without sale, denial, or delay.

(2) No person shall be deprived of legal redress for injury incurred in employment for which another person may be liable except as to fellow employees and his immediate employer who hired him if such immediate employer provides coverage under the Workmen's Compensation Laws of this state.

(3) This section shall not be construed as a limitation upon the authority of the legislature to enact statutes establishing limiting, modifying or abolishing remedies, claims for relief, damages, or allocations of responsibility for damages in any civil proceeding, except that any express dollar limits on compensatory damages for actual economic loss for bodily injury must be approved by a 2/3 vote of each house of the legislature.

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[2] Art. II, § 18, of the Montana Constitution provides: "The state, counties, cities, towns, and all other local government entities shall have no immunity from suit for injury to a person or property except as may be specifically provided by law by a 2/3 vote of each house of the legislation."

2. Exemplary or Punitive Damages

The Statutory prohibition against recovery of exemplary or punitive damages against the State,[3] (through its employees) has been upheld by the Montana Supreme Court. In White v. State, 40 St. Rep. 507 (1983), the Court without citation held the right to recover exemplary damages is not a fundamental right, and that legislative limitations thereon were subject only to a rational basis test. (The right to full redress for all injuries was held to be a fundamental right, limitation of which must pass a strict 'scrutiny test'). The Court further noted, "The problem with assessing punitive damages against the government is that the deterrent effect is extremely remote and innocent taxpayers are, in fact, the ones punished. Those taxpayers have little or no control over the actions of the guilty tortfeasor." White, at 511. That section was not changed at the June 1986, special legislative session, and it is unknown whether 1987 legislation will be introduced on this point. Although compensatory and punitive limits are expected to be enacted in 1987, because the right to recover punitive damages is only a right (as opposed to a fundamental constitutional right) any future attack on governmental immunity therefrom would have to prove the prohibition is arbitrary or capricious. Absent future legislation allowing governmental liability for punitive damages, the State is not liable therefor. That is, where a fundamental constitutional right (like compensatory damages) is in issue, the State must show a compelling State interest to justify the limitation. Where a private right, like punitive damages, is involved the State need only show rationality.

3. Limitations on Recovery of Compensatory Damages against the State

Between 1983 and December 31, 1985, the State was not liable for, "...damages suffered as a result of an act or omission of

[3] The state and other governmental entities are immune from exemplary and punitive damages. § 2-9-105, MCA, (1985).

an officer, agent, or employee of that entity in excess of $300,000 for each claimant and $1 million for each occurrence." § 2-7-107(1), MCA, (1985). Further, no insurer was liable for damages in excess of those amounts unless the insurer specifically agreed by written endorsement to be so liable. § 2-9-107(2), MCA, (1985).

In White, supra, in addition to punitive damages, these limits and absolute State immunity from non-economic damages (pain and suffering) were in issue. Both these particular limits and the absolute immunity from non-economic damages were struck under the strict scrutiny analysis. The Court held that the right to full redress for all injuries was a fundamental right, and limitations thereon were subject to the strict scrutiny or compelling state interest test.

> The State argues that it has shown a compelling state interest in "insuring that sufficient public funds will be available to enable the State and local governments to provide those services which they believe benefit their citizens and which their citizens demand." ....The District Court found that, "this 'bare assertion,' however, 'falls far short of justifying' a discrimination which infringes upon fundamental rights." We agree....We recognize that some limit on the State's liability may comport with the constitutional guarantees of equal protection. However, such a limitation cannot discriminate between those who suffer pain and loss of life quality and those who primarily suffer economically.

White, at 510.

In 1983, the legislature responded to White by repealing the faulty statute, and enacting the same monetary limits on all recovery against the State, preceded by a lengthy statement of legislative findings designed to create the evidence needed to show a compelling state interest and withstand a strict scrutiny test. This attempt was to no avail, however, and in Pfoft v. State, 42 St. Rep. 1957 (1985), the Supreme Court again struck the statutory limitations.

At the June 1986 special session, that is, before the passage of CI 30, and in response to Pfoft, the legislature again amended the statute. The governmental liability limit was temporarily raised to $750,000 for each claim and $1.5 million for each occurrence. § 2-9-107 (temporary), MCA. En. Sec. 2, Ch. 22, June 1986. After June 30, 1987, this limit is repealed, and absent further legislative action, unlimited liability would lie against the state. After the special session however, CI 30 passed, so legislative action in 1987 is certain. Until otherwise judicially decided, between July 10, 1985 and June 30, 1987, these limits apply. Dvorak and Jacques, supra. The law in effect at the time of injury applies.

3. Statutory or Rule Violation

Where dam operation is not lawful, as may be the case with the Tongue River Dam, negligence may be shown by merely proving the statutory violation. (see below for discussion of rule versus statutory violation) The new Dam Safety Law provides:

> Except as provided in subsection (2), nothing in this chapter relieves an owner of a dam or reservoir of any legal duty, obligation, or liability incident to its ownership or operation, including any damages resulting from leakage or overflow of water or floods caused by the failure or rupture of the dam or reservoir.
>
> (2) The owner of a dam or reservoir that has been permitted by the department in accordance with this chapter is not, in the absence of negligence, liable for damages resulting from flows of water from the dam or reservoir which are of sufficient magnitude to exceed the limits of the 100 year floodplain as defined in 76-5-103. In addition, the owner of any dam or reservoir that has been permitted by the department in accordance with this chapter may, without incurring liability, allow passage through the reservoir of inflows without diminution.

§ 85-15-305, MCA.

A logical reading of the statute indicates that it merely restates the common law, except that subparagraph 2 appears to insulate from liability a permitted dam owner who allows all inflows to pass through a reservoir.

Because operation of any particular dam is not illegal, there is normally no negligence per se. Of course, the reverse of that is that if the dam _were_ being operated unlawfully, all a plaintiff need prove is violation of the law, and negligence would automatically be shown. _Jeffers_, _supra_, _Heckaman_, _infra_. If operation of the dam violates the statute, and that violation is the proximate cause of the damage, the state will be liable. _Kudrna v. Comet Corp._, 175 Mont. 29, 572 P.2d 183 (1977).

Clearly any violation of the statute is likely to be found to be the proximate cause of any flood damage. The proximate cause connection is used to deny per se liability where the statutory violation is not connected with a particular accident, as for example, where an ice cream store may have violated a milk price control law, but that violation would not be connected with a patron slipping and falling on a slippery floor in the parlor. The dam safety act being intended to safeguard lives, the applicable rule in Montana is, "...the violation of a statute enacted for the safety of the public is negligence per se." _Kudrna_, at 39, quoting _Rader v. Nicholls_, 140 Mont. 459, 562, 373 P.2d 312 (1962). The statutes requiring a railroad to build its culverts safely are a good analogy. In _Peel_, _infra_, it was held that a railroad which violated statutes codifying the common law requirement of safe construction of culverts would be negligent per se. _See_ _Formicove, Inc. v. Burlington Northern, Inc._, ____Mont.____, 673 P.2d 469 (1983), for construction of a statute as imposing an affirmative duty on railroads to build the necessary ditches to drain off surface waters obstructed by its embankments.

Although violations of statutes enacted for the public safety, when the proximate cause of damage, are negligence per se, violations of administrative rules enacted pursuant to those statutes are only evidence of negligence. Whether the legislature incorporates by reference the administrative rules, thereby elevating them to the status of statutory law, is a question of fact and law in each case, _Stepanek v. Kober Construction_, ____Mont.____, 625 P.2d 51 (1981); _Cash v. Otis Elevator Co._, ____Mont.____, 684 P.2d 1041 (1984).

In <u>Cash</u>, the plaintiffs argued that the legislature mandated the adoption of the administrative safety code, and that violation of the rule was therefore negligence per se. "...the legislature did not incorporate this administrative code by reference. The legislature simply mandated that the Department of Administration adopt rules. The Department did so. The legislature did not act further to adopt those rules. Under these circumstances, the administrative code does not become part of a statute by reference. Therefore, violation of the code is evidence of negligence rather than negligence per se." <u>Cash</u> at 1045.

In <u>Lutz v. United States</u>, 685 F.2d 1178 (1982), in necessarily applying Montana law, discussed per se negligence following from a violation of a state or ordinance, "For this rule to apply, the plaintiff must be a member of the class against whom the duty is imposed by the state...; and the defendant must be a member of the class against whom a duty is imposed." <u>Lutz</u> at 1184. The federal court then applied state law and determined the base regulation for Malmstrom was closely akin to a city ordinance, because of the size of the base and the regulatory enforcement there. Since it found the regulation to be more like a municipal ordinance than an administrative regulation, violation thereof was negligence per se, rather than mere evidence of negligence.

4. <u>Dam Owner's Liability</u>

Since dam operation generally is lawful, <u>Federal Land Bank v. Morris</u>, 112 Mont. 445, 116 P.2d 1007 (1941), negligence must be pled and alleged. The normal maintenance of a dam and resulting normal water level fluctuations and hydrologic conditions, eg., icing, run-off changes, etc., are not a nuisance per se. <u>Jeffers v. Montana Power Co.</u>, 68 Mont. 114, 217 P. 652 (1923). Persons impounding water are held to normal standard of care. Several cases arose from a 1929 flood in Wibaux, alleged to have been aggravated by an inadequate railroad bridge. In <u>Heckaman v Northern Pac. Ry. Co.</u>, 93 Mont. 363, 20 P.2d 258 (1933), the defendant relied on three legal defenses: a) that any negligence must date from the design and construction of the faulty embankment in 1898, so the cause was barred by the statute of limitations, b) plaintiff acquired property with

knowledge or at least subsequent to the danger and the presence of the bridge so took the property subject to the hazard, and, c) the flood was so great that it was properly found to be an unforseeable act of God, for which the defendant cannot be liable.

The statute of limitations and pre-existing danger defenses failed because the cause of action did not accrue until the property damage occurred. The Act of God defense failed because the defendant had already been found negligent for having obstructed the predictable flow of the river. The Court held, "The general rule is that the plaintiff is required to allege and prove actionable negligence; a duty owing to him by the defendant, and its breach; negligence in the construction or maintenance of the embankment which constituted the proximate cause of the damage he suffered," at 376. The railroad was statutorily bound to restore any streams or watercourses it crossed to, "its former state of usefulness, as near as may be, or so that the railroad shall not unnecessarily impair its usefulness or injure its function," at 378. The duty to maintain is continuing, and construction appearing adequate at that time must be altered if subsequent events impair it or prove it to be inadequate. The plaintiffs in <u>Heckaman</u> showed the 1929 flood to be predictable based on the experiences of flood in 1904, 1921, and that the bridge had been insufficient to pass those flows.

The Court in <u>Heckaman</u> corrected an offered instruction more accurately to reflect the law. Corrected, it reads:

> Before the plaintiff can recover against the defendants, the plaintiff must prove that a proximate cause of the damage to plaintiff's property was the negligence of the defendants; it must appear from the evidence that the damage was the natural and probable consequence of the negligence of the defendants and that damage ought to have been foreseen by the defendants in the light of the attending circumstances. The first requisite of a proximate cause is the doing or omitting to do an act which a man of ordinary prudence could foresee might naturally and probably produce damage and the second requisite is that such act or omission did actually cause the

> damage. If, therefore, you find from a preponderance of the evidence that in constructing said embankment and openings therein, as they existed at the time of this flood, a person of ordinary prudence would not have foreseen the flood of June 7, 1929, or if you find that the property of the plaintiff would have been damaged had said embankment and openings therein never existed, then the construction of said embankment and openings, as the evidence shows the same existed, was not a proximate cause of the damage to plaintiff's property and the defendants are not liable in law.

In Wibaux v. Northern Pacific Railway, Co., 101 Mont. 126, 54 P.2d 1175 (1935), the Court affirmed that a dam owner is held to a normal standard of care, and is not an insurer for all damages resulting from the prudent operation of a dam. Plaintiffs sued Northern Pacific Railway for flood damages arising from the concurrence of an Act of God and the defendant's negligent design of a railway embankment and bridge. The plaintiffs in Heckaman, supra, arising from the same occurrence, prevailed, but those in Wibaux did not. The Court's discussion of instructions in issue again indicated its preferred evidence.

> In substance, the instruction counsel contend for would hold defendant liable without allowing the history of the stream or of any flood prior to 1929 at Wibaux to be considered. In our opinion, these are the most essential elements that could be employed to measure the skill, care and prudence necessary in the premises. From such sources, the knowledge is acquired by which the essential degree of care, prudence and skill is measured.

Wibaux at 133.

The railroad having been overruled on its legal defenses in Heckaman, Wibaux established a strong factual record that the bridge had not actually been inadequate to pass prior floods, that it had not actually had notice of the town's allegation that the opening in the bridge was inadequate, and that the flood was of an unprecedented magnitude. Although the lower

court's record was conflicting in Wibaux, the Supreme Court found substantial credible evidence to support the verdict. Interestingly, the evidentiary rulings by the trial court judges made the difference between these two cases.

The ability of a structure safely to have passed all prior floods seems a key factor in the negligence determination. In Peel, et al. v. Chicago, Milwaukee, St. Paul & Pacific Railroad, 94 Mont. 334, 22 P.2d 617 (1933), the Court reversed a jury verdict for plaintiffs because the evidence showed the storm was far greater than the normal, predictable spring floods, and that the structure had safely passed all prior floods. Although it was found that flooding was relatively common, all prior "usual" floods had been no problem for the structure, so no negligence existed even though the structure could not withstand the Act of God flood. The Court held, "When a railroad corporation constructs and maintains culverts and bridges which are in fact insufficient properly to provide for the passage of such waters as are reasonable to be expected, then it violates the statute (Rev. Codes 1921, sec. 6507, sub. 5) and by virtue of such violation becomes negligent per se," Peel at 341.

The differing results in Heckaman and Wibaux illustrate the importance of the factual record. Here, of course, we are dealing with a predicted failure. It could be inferred from these cases that failure to correct a predicted failure is negligence per se. In Barr v. Game, Fish, and Parks Commission, ____Colo.____, 497 P.2d 340 (1972), the dam owner was liable for damages caused after a flood event of 158,000 cfs, where the spillway as built would pass only 4500 cfs but the spillway capacity as originally designed was 33,800. The PMF was 200,000. Section 85-15-305(2), MCA, (1985), arguably sets the "Act of God" defense at the 100 year floodplain. That is, any dam capable of passing up to the amount should be 'safe.'

5. Agency Considerations

Regarding who will be the liable entity, the owner/occupier will be liable whenever it knew, or should have known, of the unreasonably dangerous condition. An agent of the owner/occupier will share liability only when the agent is in control of the premises, and has the duty and means to correct the faulty conditions. The agent must be responsible for the site, and have the authority, duty, and means to act.

> It is, of course, essential to the liability of the agent in these cases, that he shall be responsible for the condition. If the premises were in the defective condition when they came under his charge, and he has neither the power nor the authority to change them, or if the defect arose while they were in his charge, but he had no power or authority to correct it, he could ordinarily not be held responsible.

Richland County v. Anderson, 129 Mont. 559-567, 291 P.2d 267 (1955).

And, if that agent is an independent contractor instead of an employee, (s)he will be liable for punitive damages, i.e. is not entitled to immunity from punitive damages, or to the upper limit on the State's damages. Kyriss v. State, 707 P.2d 5 (1985).

6. Damage Apportionment

Regarding apportionment of damages, Heckaman held that, "If in a given case, it is conceded or shown that damage would have resulted regardless of the existence of an embankment, but additional damage was suffered by reason of the negligent maintenance of the embankment, the plaintiff must produce evidence as to the amount of damage for which defendant is liable," at 388.

The magnitude of flood damage needn't be foreseen if the type or fact of damage is. "For the breach of an obligation not arising from contract, the measure of damages, except where otherwise expressly provided by this code, is the amount which will compensate for all the detriment proximately caused thereby, whether it could have been anticipated or not." § 27-1-317, MCA, (1985).

Given the importance of the record, as demonstrated in the opposite verdicts in Heckaman, and Wibaux Realty, supra, further research is necessary to estimate parameters for probable liability amounts.

7. <u>Elements of Compensatory Damages</u>

Currently, the State would be liable for damages proximately caused by its negligence. This includes economic and non-economic damages. Economic damages are those calculated on the basis of calculable loss, eg., lost or diminished capacity of an individual, business entity, land, medical costs, housing and property damages, etc. Non-economic damages include loss of consortion, pain and suffering, reduced capacity to enjoy life, etc. White, supra, Pfoff, supra. For all deaths, the liable party must answer for the decedent's own causes of action, which survive the death, as well as causes of action for 'wrongful death' through which parties injured by the death bring action for their own injuries. Swanson v. Champion International Comp., 197 Mont. 509, 646 P.2d 1166 (1982).

The death does not extinguish any causes of action the decedent had, and these pass to the estate the personal representative then brings the action on behalf of the estate, and, proceeds therefrom are an asset of the estate like any other.[4] This type of action includes, for examples claims for money judgments, or actions for breach of contract obligation, as well as damages for personal pain and suffering and injury.

The parents or guardian of a minor may bring suit for his or her injury or death. § 27-1-512, MCA, (1985). The heirs or personal representatives of the adult decedent are empowered to bring the wrongful death action for their own injuries. § 27-1-513, MCA, (1985).

---

[4] Section 27-1-501, MCA (1985), provides, "An action does not abate because of the death or disability of a party...but whenever the cause of action or defense arose in favor of such party prior to his death or disability...it survives and may be maintained by his representatives or successors in interest."

8. Financial Feasibility of Repair

Lack of funds to repair the dam is no defense. That is, the State is not absolved from making the dam safe merely because it is financially incapable of doing so. In State v. District Court, 175 Mont. 63, 572 P.2d 201 (1977), the Court held:

> Financial feasibility or discretion "...is no...defense under the common law, any Montana Statute, or Montana's Constitution." The defense rests on the premise that because the legislature fails to appropriate sufficient funds to deal adequately with all of the hazards in the state highway system the Department of Highways must exercise its discretion in allocating funds to deal with these hazards, and should not be held accountable when it can be shown that it was negligent in doing so.
>
> As noted, the Tort Claims Act attached liability to the State in the same manner and to the same extent that liability attaches to a private person.[5] [citation omitted]. There is no common or statutory law which permits the driver of a brakeless car to plead he could not afford brakes because he had decided it was more important to pay his grocery bill. When he drives, the motorist assumes the duty of driving a safe car. If he fails to discharge that duty and that failure results in injury he is liable, regardless of his personal financial priorities. So too, with the State. Whenever and wherever it chooses to build highways, it assumes the duty of building and maintaining them safely and is answerable if it fails to do so. This does not, as argued by relator, make the state an insurer any more than it makes a private

---

[5] This is not entirely true since that Act also established a predecessor to the existing upper limit. The upper limit was not in issue in this case.

> party an insurer. The negligence of the state must still be proven. It simply withholds from the State a defense a private party never had.

State at 67.

This hard-line was softened in Modrell v. State, 179 Mont. 498, 587 P.2d 405 (1978). Another highway case, Modrell held that while financial feasibility is not a defense:

> We can, however, carry this analogy only so far. The State's duty to maintain and design safe highways is different than the duty of a driver to drive a safe car. Clearly, evidence of a driver's decision to pay for groceries before brakes is irrelevant on the issue of an allegedly breached duty of care. It has no legal bearing on the course of conduct taken. But the duty of the state to construct and maintain roadways in a reasonably safe condition stands on a different footing. Factors entering into the decision to elect one alternative over another are relevant to the extent that they bear as evidence in the reasonableness of the decision. The alternatives selected must be realistic, viable and subject to the state-of-the-art limitations. Obviously, cost must be a factor.
>
> To be sure, reliance on cost as the sole and determining factor would be tantamount to assertion of a financial feasibility defense and therefore impermissible. However, where cost is but one among many factors affecting the State's choice of a particular method of construction or maintenance of it is relevant evidence on the reasonableness of the alternative taken.

Modrell at 500, 501.

The proper instruction was, "If you find the defendant negligent in planning or constructing or maintaining the highway in

question, you may not excuse such negligence on the ground that proper construction was beyond the financial means of the State. Cost is not factor in duty of the State to plan, construct and maintain its highways in a reasonable safe condition." Modrell at 501.

Hence, the State has a duty to maintain the dam in a reasonably safe condition, regardless of cost. The means by which this safety is achieved may, however, be partially dictated by cost concerns.

SB:bb

APPENDIX B

RISK ASSESSMENT SPREADSHEETS

ALL ALTERNATIVES

LOADING		SYSTEM RESPONSE			OUTCOME				ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12) ANNUAL RISK COST ($*10**6)	(13) ANNUAL RISK COST ($*10**6)	(14) ANNUAL RISK COST ($*10**6)	(15) (TOTAL/ EVENT)	(16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
HYDROLOGIC - SPRING FLOOD (PEAK INFLOW IN K. CFS)																		
0-10	9.75E-01	NO FAIL (& PF)	1		3425.4	1		0.975										
(0-7)		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000	590	0.00E+00						0.000	DAM-BIRNEY	114	0.075000	8.6
									275.75	0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000	580	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									275.75		0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000	590	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									275.75			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	590	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									275.75				0.000		BELOW BIRNEY	10032	0.000200	2.0
10-15	1.80E-02	NO FAIL (& PF)	0.85		3427.2	1		0.0171										
(7-11)		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000	830	0.00E+00						0.251	DAM-BIRNEY	114	0.075000	8.5
									278.8	0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0500															
				F STILL B.		1.0000	830	9.00E-04							DAM-BIRNEY	114	0.075000	8.5
									278.8		0.251				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000	830	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									278.8			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	830	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									278.8				0.000		BELOW BIRNEY	10032	0.000200	2.0
15-20	4.00E-03	NO FAIL (& PF)	0.85		3428.8	1		0.0034										
(11-16)		SPILL CREST F	0.0500															
				F - SPILLWAY		1.0000	870	2.00E-04						0.168	DAM-BIRNEY	114	0.075000	8.5
									280.8	0.058					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.1000															
				F STILL B.		1.0000	870	4.00E-04							DAM-BIRNEY	114	0.075000	8.5
									280.8		0.112				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000	870	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									280.8			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	870	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									280.8				0.000		BELOW BIRNEY	10032	0.000200	2.0
20-25	8.00E-04	NO FAIL (& PF)	0.85		3430	1		0.00052										
(16-20)		SPILL CREST F	0.2000															
				F - SPILLWAY		1.0000	890	1.80E-04						0.079	DAM-BIRNEY	114	0.075000	8.5
									281.3	0.045					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.1500															
				F STILL B.		1.0000	890	1.20E-04							DAM-BIRNEY	114	0.075000	8.5
									281.3		0.034				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000	890	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									281.3			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	890	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									281.3				0.000		BELOW BIRNEY	10032	0.000200	2.0

LOADING		SYSTEM RESPONSE			OUTCOME				ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12) ANNUAL RISK COST ($*10**6)	(13) ANNUAL RISK COST ($*10**6)	(14) ANNUAL RISK COST ($*10**6)	(15) (TOTAL/ EVENT)	(16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
25-30 [20-24]	8.00E-04	NO FAIL (& PF)	0.45		3431	1		0.00038										
		SPILL CREST F	0.3000	F - SPILLWAY		1.0000	710	2.40E-04						0.124	DAM-BIRNEY	114	0.075000	8.5
									282.5	0.068					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.2500	F STILL B.		1.0000	710	2.00E-04							DAM-BIRNEY	114	0.075000	8.5
									282.5		0.057				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000	710	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									282.5			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	710	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									282.5				0.000		BELOW BIRNEY	10032	0.000200	2.0
30-50 [24-42]	8.00E-04	NO FAIL (& PF)	0.15		3433.2	1		0.00012										
		SPILL CREST F	0.4000	F - SPILLWAY		1.0000	880	3.20E-04						0.187	DAM-BIRNEY	114	0.075000	8.5
									289.5	0.083					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.4000	F STILL B.		1.0000	880	3.20E-04							DAM-BIRNEY	114	0.075000	8.5
									288.5		0.093				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0500	F SPILLWAY		1.0000	880	4.00E-05							DAM-BIRNEY	114	0.075000	8.5
									289.5			0.012			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	880	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									289.5				0.000		BELOW BIRNEY	10032	0.000200	2.0
50-80 [42-68]	3.00E-04	NO FAIL (& PF)	0		3437.3	1		0										
		SPILL CREST F	0.4500	F - SPILLWAY		1.0000	1130	1.35E-04						0.088	DAM-BIRNEY	114	0.075000	8.5
									287	0.040					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.4500	F STILL B.		1.0000	1130	1.35E-04							DAM-BIRNEY	114	0.075000	8.5
									287		0.040				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.1000	F SPILLWAY		1.0000	1130	3.00E-05							DAM-BIRNEY	114	0.075000	8.5
									287			0.009			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	1130	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									287				0.000		BELOW BIRNEY	10032	0.000200	2.0
80-110 [68-103]	1.80E-04	NO FAIL (& PF)	0		3441.8	1		0										
		SPILL CREST F	0.4500	F - SPILLWAY		1.0000	1390	8.10E-05						0.055	DAM-BIRNEY	114	0.075000	8.5
									303	0.025					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.4500	F STILL B.		1.0000	1390	8.10E-05							DAM-BIRNEY	114	0.075000	8.5
									303		0.025				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.1000	F SPILLWAY		1.0000	1390	1.80E-05							DAM-BIRNEY	114	0.075000	8.5
									303			0.005			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	1390	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									303				0.000		BELOW BIRNEY	10032	0.000200	2.0

LOADING		SYSTEM RESPONSE			OUTCOME				ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12) ANNUAL RISK COST ($*10**6)	(13) ANNUAL RISK COST ($*10**6)	(14) ANNUAL RISK COST ($*10**6)	(15) (TOTAL/ EVENT)	(16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
110-200 (103-198)	8.00E-05	NO FAIL (& PF)	0		3443.7	1		0										
		SPILL CREST F	0.4500	F - SPILLWAY		1.0000	1650	3.80E-05	308	0.011				0.025	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.4500	F STILL B.		1.0000	1650	3.80E-05	308		0.011				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.1000	F SPILLWAY		1.0000	1550	8.00E-06	398			0.003			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	1550	0.00E+00	308				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
200-382 (198-378)	3.00E-05	NO FAIL (& PF)	0		3444.7	1		0										
		SPILL CREST F	0.4500	F - SPILLWAY		1.0000	1880	1.35E-05	309.5	0.004				0.009	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.4500	F STILL B.		1.0000	1880	1.35E-05	309.5		0.004				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.1000	F SPILLWAY		1.0000	1680	3.00E-06	309.5			0.001			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	1880	0.00E+00	309.5				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
>382 (>378)	1.00E-05	NO FAIL (& PF)	0		3445.8	1		0										
		SPILL CREST F	0.4500	F - SPILLWAY		1.0000	1750	4.50E-06	311	0.001				0.003	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.4500	F STILL B.		1.0000	1750	4.50E-06	311		0.001				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.1000	F SPILLWAY		1.0000	1750	1.00E-06	311			0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	1750	0.00E+00	311				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
							TOTAL	3.50E-03	TOTAL =	0.343	0.827	0.030	0.000					

Annual Risk Cost (Spring Flood Event) = 1.001

LOADING		SYSTEM RESPONSE			OUTCOME				ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12) ANNUAL RISK COST ($*10**6)	(13) ANNUAL RISK COST ($*10**6)	(14) ANNUAL RISK COST ($*10**6)	(15) (TOTAL/ EVENT)	(16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
HYDROLOGIC - SUMMER FLOOD (INFLOWS IN K. CFS)																		
0-10	0.99955	NO FAIL (& PF)	1		3424.4	1		0.99958										
(2)		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000	580	0.00E+00						0.000	DAM-BIRNEY	114	0.075000	8.5
									273	0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000	580	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									273		0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000	580	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									273			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	580	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
10-15	1.50E-04	NO FAIL (& PF)	0.87		3424.7	1		0.000145	273				0.000		BELOW BIRNEY	10032	0.000200	2.0
(4.5)		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000	570	0.00E+00						0.001	DAM-BIRNEY	114	0.075000	8.5
									274	0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0300															
				F STILL B.		1.0000	570	4.50E-08							DAM-BIRNEY	114	0.075000	8.5
									274		0.001				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000	570	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									274			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	570	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									274				0.000		BELOW BIRNEY	10032	0.000200	2.0
15-20	1.00E-04	NO FAIL (& PF)	0.9		3425	1		0.00009										
(5)		SPILL CREST F	0.0300															
				F - SPILLWAY		1.0000	575	3.00E-08						0.003	DAM-BIRNEY	114	0.075000	8.5
									274.5	0.001					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0700															
				F STILL B.		1.0000	575	7.00E-08							DAM-BIRNEY	114	0.075000	8.5
									274.5		0.002				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000	575	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									274.5			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	575	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									274.5				0.000		BELOW BIRNEY	10032	0.000200	2.0
20-25	8.00E-05	NO FAIL (& PF)	0.75		3425.4	1		0.00006										
(5.5)		SPILL CREST F	0.1600															
				F - SPILLWAY		1.0000	585	1.28E-05						0.006	DAM-BIRNEY	114	0.075000	8.5
									275.37	0.004					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0900															
				F STILL B.		1.0000	585	7.20E-08							DAM-BIRNEY	114	0.075000	8.5
									275.37		0.002				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000	585	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									275.37			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	585	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									275.37				0.000		BELOW BIRNEY	10032	0.000200	2.0

LOADING		SYSTEM RESPONSE			OUTCOME				ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12) ANNUAL RISK COST ($*10**6)	(13) ANNUAL RISK COST ($*10**6)	(14) ANNUAL RISK COST ($*10**6)	(15) (TOTAL/ EVENT)	(16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
25-30 (8.5)	4.00E-05	NO FAIL (& PF)	0.65		3425.8	1		0.000022										
		SPILL CREST F	0.2800															
				F - SPILLWAY		1.0000	585	1.12E-05						0.005	DAM-BIRNEY	114	0.075000	8.5
									278.12	0.003					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.1700															
				F STILL B.		1.0000	585	8.80E-06							DAM-BIRNEY	114	0.075000	8.5
									278.12		0.002				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000	585	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									278.12			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	585	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									278.12				0.000		BELOW BIRNEY	10032	0.000200	2.0
30-60 (8.5)	4.00E-06	NO FAIL (& PF)	0.2		3428.7	1		0.000008										
		SPILL CREST F	0.3800															
				F - SPILLWAY		1.0000	710	1.52E-05						0.008	DAM-BIRNEY	114	0.075000	8.5
									282.5	0.004					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.3800															
				F STILL B.		1.0000	710	1.52E-05							DAM-BIRNEY	114	0.075000	8.5
									282.5		0.004				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0400															
				F SPILLWAY		1.0000	710	1.80E-06							DAM-BIRNEY	114	0.075000	8.5
									282.5			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	710	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									282.5				0.000		BELOW BIRNEY	10032	0.000200	2.0
50-80 (8)	3.00E-05	NO FAIL (& PF)	0		3428.5	1		0										
		SPILL CREST F	0.4500															
				F - SPILLWAY		1.0000	845	1.35E-05						0.008	DAM-BIRNEY	114	0.075000	8.5
									288	0.004					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.4500															
				F STILL B.		1.0000	845	1.35E-05							DAM-BIRNEY	114	0.075000	8.5
									289		0.004				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.1000															
				F SPILLWAY		1.0000	845	3.00E-06							DAM-BIRNEY	114	0.075000	8.5
									288			0.001			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	845	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									288				0.000		BELOW BIRNEY	10032	0.000200	2.0
80-110 (15.5)	1.00E-05	NO FAIL (& PF)	0		3429.5	1		0										
		SPILL CREST F	0.4500															
				F - SPILLWAY		1.0000	945	4.50E-06						0.003	DAM-BIRNEY	114	0.075000	8.5
									282.1	0.001					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.4500															
				F STILL B.		1.0000	845	4.50E-06							DAM-BIRNEY	114	0.075000	8.5
									282.1		0.001				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.1000															
				F SPILLWAY		1.0000	945	1.00E-06							DAM-BIRNEY	114	0.075000	8.5
									292.1			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	845	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									292.1				0.000		BELOW BIRNEY	10032	0.000200	2.0

LOADING		SYSTEM RESPONSE			OUTCOME				ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12) ANNUAL RISK COST ($*10**6)	(13) ANNUAL RISK COST ($*10**6)	(14) ANNUAL RISK COST ($*10**6)	(15) (TOTAL/ EVENT)	(16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(18) LOSS OF LIFE PER EVENT
110-200	8.00E-08	NO FAIL (& PF)	0		3433.7	1		0										
(38.5)		SPILL CREST F	0.4500															
				F - SPILLWAY		1.0000	1115	2.70E-08						0.002	DAM-BIRNEY	114	0.075000	8.5
									298.5	0.001					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.4500															
				F STILL B.		1.0000	1115	2.70E-08							DAM-BIRNEY	114	0.075000	8.5
									298.5		0.001				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.1000															
				F SPILLWAY		1.0000	1115	6.00E-07							DAM-BIRNEY	114	0.075000	8.5
									298.5			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	1115	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									298.5				0.000		BELOW BIRNEY	10032	0.000200	2.0
200-382	3.00E-08	NO FAIL (& PF)	0		3439.8	1		0										
(87)		SPILL CREST F	0.4500															
				F - SPILLWAY		1.0000	1215	1.35E-08						0.001	DAM-BIRNEY	114	0.075000	8.5
									300	0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.4500															
				F STILL B.		1.0000	1215	1.35E-08							DAM-BIRNEY	114	0.075000	8.5
									300		0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.1000															
				F SPILLWAY		1.0000	1215	3.00E-07							DAM-BIRNEY	114	0.075000	8.5
									300			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	1215	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									300				0.000		BELOW BIRNEY	10032	0.000200	2.0
>382	1.00E-08	NO FAIL (& PF)	0		3448.2	1		0										
(>122)		SPILL CREST F	0.4500															
				F - SPILLWAY		1.0000	1580	4.50E-07						0.000	DAM-BIRNEY	114	0.075000	8.5
									308	0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.4500															
				F STILL B.		1.0000	1580	4.50E-07							DAM-BIRNEY	114	0.075000	8.5
									308		0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.1000															
				F SPILLWAY		1.0000	1580	1.00E-07							DAM-BIRNEY	114	0.075000	8.8
									308			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	1580	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									308				0.000		BELOW BIRNEY	10032	0.000200	2.0
							TOTAL	1.35E-04	TOTAL =	0.018	0.018	0.002	0.000					

Annual Risk Cost (Summer Flood Event) = 0.038

LOADING		SYSTEM RESPONSE			OUTCOME				ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**8)	(11) ANNUAL RISK COST ($*10**8)	(12)	(13)	(14)	(15)	(16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
SEISMIC - (MAGNITUDE)																		
M 0. - 5.5	1.00E-02	NO FAIL (& PF)	1		3424.4	1		0.01		0								
(0 -.08g)		RES. LANDSLIDE	0															
				F - BREACH		0.0000	560	0.00E+00							DAM - BIRNEY	114	0.150000	17.1
									273	0					BELOW BIRNEY	10032	0.000200	2.0
		FOUNDAT LIQ	0.0000															
				F - BREACH		0.0000	560	0.00E+00							DAM - BIRNEY	114	0.150000	17.1
									273	0					BELOW BIRNEY	10032	0.000200	2.0
		EMB. DEFOR.	0.0000															
				F - BREACH		0.0000	580	0.00E+00							DAM - BIRNEY	114	0.150000	17.1
									273	0					BELOW BIRNEY	10032	0.000200	2.0
		CORE CRACK/PIPE	0.1000															
				F - BREACH		0.0000	680	0.00E+00							DAM - BIRNEY	114	0.150000	17.1
									273	0					BELOW BIRNEY	10032	0.000200	2.0
		OUTLET-RUPTURE	0.2500															
				F - BREACH		0.0000	680	0.00E+00							DAM - BIRNEY	114	0.150000	17.1
									273	0					BELOW BIRNEY	10032	0.000200	2.0
M>5.5	1.00E-03	NO FAIL (& PF)	0.998			1		0.000998		0								
(>.08g)		RES. LANDSLIDE	0.001															
				F - BREACH		0.0000	580	0.00E+00							DAM - BIRNEY	114	0.150000	17.1
									273	0					BELOW BIRNEY	10032	0.000200	2.0
		FOUNDAT LIQ	0.0010															
				F - BREACH		1.0000	580	1.00E-08							DAM - BIRNEY	114	0.150000	17.1
									273	0					BELOW BIRNEY	10032	0.000200	2.0
		EMB. DEFOR.	0.0000															
				F - BREACH		0.0000	680	0.00E+00							DAM - BIRNEY	114	0.150000	17.1
									273	0					BELOW BIRNEY	10032	0.000200	2.0
		CORE CRACK/PIPE	0.0000															
				F - BREACH		0.0000	580	0.00E+00							DAM - BIRNEY	114	0.150000	17.1
									273	0					BELOW BIRNEY	10032	0.000200	2.0
		OUTLET-RUPTURE	0.0000															
				F - BREACH		0.0000	560	0.00E+00							DAM - BIRNEY	114	0.150000	17.1
									273	0					BELOW BIRNEY	10032	0.000200	2.0
							TOTAL	1.00E-08	TOTAL	0.000273								

Annual Risk Cost (Seismic Event)= 0.000273

Tongue River Dam Risk Analysis — ALTERNATIVE A, EXISTING DAM — Static Events

LOADING		SYSTEM RESPONSE			OUTCOME				ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12)	(13)	(14)	(15)	(16) POPULATION AT RISK	(17) EXPOSURE PROB	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
STATIC - FOUNDATION																		
	1.00E+00	EMB. DEFOR.	3.80E-05	F - BREACH	3424.4	1.0000	580	3.80E-05		0.000					DAM - BIRNEY	114	0.150000	17.1
									273	0.010					BELOW BIRNEY	10032	0.000200	2.0
									TOTAL =	0.010								
STATIC - PIPING EMBANKMENT																		
	1.00E+00	PIPING	1.20E-05	F - BREACH		1.0000	580	1.20E-05		0.000					DAM - BIRNEY	114	0.150000	17.1
									273	0.003					BELOW BIRNEY	10032	0.000200	2.0
									TOTAL =	0.003								
STATIC - SLOPE STABILITY																		
	1.00E+00	EMB. DEFOR.	2.80E-06	F - BREACH		1.0000	580	2.80E-06		0.000					DAM - BIRNEY	114	0.150000	17.1
									273	0.001					BELOW BIRNEY	10032	0.000200	2.0
									TOTAL =	0.001								
STATIC - PIPING OUTLET WORKS																		
	1.00E+00	PIPING/GATE F	1.80E-06	F - BREACH		1.0000	580	1.80E-06		0.000					DAM - BIRNEY	114	0.150000	17.1
									273	0.000					BELOW BIRNEY	10032	0.000200	2.0
									TOTAL =	0.000								
STATIC - LANDSLIDE INTO RESERVOIR																		
	1.00E-02	SEICHE	1.00E-03			1.0000									DAM - BIRNEY	114	0.150000	17.1
				F-BREACH		0.0000	580	0.00E+00	273	0.000					BELOW BIRNEY	10032	0.000200	2.0
							TOTAL	5.24E-05	TOTAL =	0.000								

Annual Risk Cost (Static Event)= 0.014306

ANNUAL RISK COST FOR LOADING EVENTS = 1.053
ANNUAL RISK COST FOR DAM REPLACEMENT = 0.553

ANNUAL RISK COST FOR ALTERNATIVE = 1.606 Million $

ALTERNATIVE A, EXISTING DAM

LOSS-OF LIFE PROBABILITIES

TOTAL	LOSS-OF-LIFE			PROBABILITY
	0	TO	15	3.63E-03
	0	TO	25	3.69E-03
	MORE THAN		25	0.00E+00

HYDROLOGIC EVENT	LOSS-OF-LIFE			PROBABILITY
	0	TO	15	3.63E-03
	MORE THAN		15	0.00E+00

SEISMIC EVENT	LOSS-OF-LIFE			PROBABILITY
	0	TO	25	1.00E-06
	MORE THAN		25	0.00E+00

STATIC EVENT	LOSS-OF-LIFE			PROBABILITY
	0	TO	25	5.24E-05
	MORE THAN		25	0.00E+00

LOADING (1) EVENT TYPE	(2) EVENT PROB	SYSTEM RESPONSE (3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	OUTCOME (6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	ECONOMIC DAMAGE (10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12) ANNUAL RISK COST ($*10**6)	(13) ANNUAL RISK COST ($*10**6)	(14) ANNUAL RISK COST ($*10**6)	(15) (TOTAL/ EVENT)	THREAT TO LIFE (16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
HYDROLOGIC - SPRING FLOOD (PEAK INFLOW IN K. CFS)																		
0-10	8.75E-01	NO FAIL (& PF)	1			1		0.875										
(0-8)		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000		0.00E+00						0.000	DAM-BIRNEY	114	0.075000	8.5
										0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
											0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
												0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
													0.000		BELOW BIRNEY	10032	0.000200	2.0
10-15	1.80E-02	NO FAIL (& PF)	1			1		0.018										
(8-12)		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000		0.00E+00						0.000	DAM-BIRNEY	114	0.075000	8.5
										0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
											0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
												0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
													0.000		BELOW BIRNEY	10032	0.000200	2.0
15-20	4.00E-03	NO FAIL (& PF)	1			1		0.004										
(12-16)		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000		0.00E+00						0.000	DAM-BIRNEY	114	0.075000	8.5
										0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
											0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
												0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
													0.000		BELOW BIRNEY	10032	0.000200	2.0
20-25	8.00E-04	NO FAIL (& PF)	1			1		0.0008										
(16-20)		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000		0.00E+00						0.000	DAM-BIRNEY	114	0.075000	8.5
										0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
											0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
												0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
													0.000		BELOW BIRNEY	10032	0.000200	2.0

LOADING		SYSTEM RESPONSE		OUTCOME					ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12) ANNUAL RISK COST ($*10**6)	(13) ANNUAL RISK COST ($*10**6)	(14) ANNUAL RISK COST ($*10**6)	(15) (TOTAL/ EVENT)	(16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
25-30 (20-25)	8.00E-04	NO FAIL (& PF)	1			1		0.0008										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000		0.00E+00		0.000				0.000	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000		0.00E+00			0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000		0.00E+00				0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000		0.00E+00					0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
30-50 (25-44)	8.00E-04	NO FAIL (& PF)	1			1		0.0008										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000		0.00E+00		0.000				0.000	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000		0.00E+00			0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000		0.00E+00				0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000 0.0000	F - BREACH		1.0000		0.00E+00					0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
50-80 (44-70)	3.00E-04	NO FAIL (& PF)	0			1		0										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000		0.00E+00		0.000				0.000	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000		0.00E+00			0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000		0.00E+00				0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000		0.00E+00					0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
80-110 (70-103)	1.80E-04	NO FAIL (& PF)	1			1		0.00018										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000		0.00E+00		0.000				0.000	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000		0.00E+00			0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000		0.00E+00				0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000		0.00E+00					0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0

LOADING		SYSTEM RESPONSE		OUTCOME					ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12) ($*10**6)	(13) ($*10**6)	(14) ($*10**6)	(15) (TOTAL/ EVENT)	(16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
110-200 (103-188)	8.00E-05	NO FAIL (& PF)	1			1		0.00008										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000		0.00E+00		0.000				0.000	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000		0.00E+00			0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000		0.00E+00				0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000		0.00E+00					0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
200-382 (188-388)	3.00E-05	NO FAIL (& PF)	0.95		3454.8	1		0.000028										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000	2185	0.00E+00	318	0.000				0.000	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000	2185	0.00E+00	318		0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0500	F SPILLWAY		1.0000	2185	1.50E-06	318			0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	2185	0.00E+00	318				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
>382 (>388)	1.00E-05	NO FAIL (& PF)	0.85		3483.4	1		0.000008										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000	2550	0.00E+00	321	0.000				0.000	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000	2550	0.00E+00	321		0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0500	F SPILLWAY		1.0000	2550	5.00E-07	321			0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.1000	F - BREACH		1.0000	2550	1.00E-06	321				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
							TOTAL	3.00E-06	TOTAL =	0.000	0.000	0.001	0.000					

Annual Risk Cost(Spring Flood Event)= 0.001

LOADING		SYSTEM RESPONSE		OUTCOME					ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12) ANNUAL RISK COST ($*10**6)	(13) ANNUAL RISK COST ($*10**6)	(14) ANNUAL RISK COST ($*10**6)	(15) (TOTAL/ EVENT)	(16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
HYDROLOGIC - SUMMER FLOOD (INFLOWS IN K. CFS)																		
0-10	0.89955	NO FAIL (& PF)	1			1		0.99955										
(4)		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000		0.00E+00						0.000	DAM-BIRNEY	114	0.075000	8.5
										0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
											0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
												0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
													0.000		BELOW BIRNEY	10032	0.000200	2.0
10-15	1.80E-04	NO FAIL (& PF)	1			1		0.00015										
(8)		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000		0.00E+00						0.000	DAM-BIRNEY	114	0.075000	8.5
										0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
											0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
												0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
													0.000		BELOW BIRNEY	10032	0.000200	2.0
15-20	1.00E-04	NO FAIL (& PF)	1			1		0.0001										
(8)		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000		0.00E+00						0.000	DAM-BIRNEY	114	0.075000	8.5
										0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
											0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
												0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
													0.000		BELOW BIRNEY	10032	0.000200	2.0
20-25	8.00E-05	NO FAIL (& PF)	1			1		0.00008										
(8.5)		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000		0.00E+00						0.000	DAM-BIRNEY	114	0.075000	8.5
										0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
											0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
												0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
													0.000		BELOW BIRNEY	10032	0.000200	2.0

LOADING (1) EVENT TYPE	(2) EVENT PROB	SYSTEM RESPONSE (3) RESPONSE TYPE	(4) RESPONSE PROB	OUTCOME (5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	ECONOMIC DAMAGE (10) PER EVENT ($*10**6)	(11) ($*10**6)	(12) ANNUAL RISK COST ($*10**6)	(13) ($*10**6)	(14) ($*10**6)	(15) (TOTAL/ EVENT)	THREAT TO LIFE (16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
25-30 (9.5)	4.00E-05	NO FAIL (& PF)	1			1		0.00004										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000		0.00E+00		0.000				0.000	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000		0.00E+00			0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000		0.00E+00				0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000		0.00E+00					0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
30-50 (12)	4.00E-05	NO FAIL (& PF)	1			1		0.00004										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000		0.00E+00		0.000				0.000	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000		0.00E+00			0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000		0.00E+00				0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000		0.00E+00					0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
50-80 (17)	3.00E-05	NO FAIL (& PF)	1			1		0.00003										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000		0.00E+00		0.000				0.000	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000		0.00E+00			0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000		0.00E+00				0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000		0.00E+00					0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
80-110 (24)	1.00E-05	NO FAIL (& PF)	1			1		0.00001										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000		0.00E+00		0.000				0.000	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000		0.00E+00			0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000		0.00E+00				0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000		0.00E+00					0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0

LOADING		SYSTEM RESPONSE			OUTCOME				ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12) ANNUAL RISK COST ($*10**6)	(13) ANNUAL RISK COST ($*10**6)	(14) ANNUAL RISK COST ($*10**6)	(15) (TOTAL/ EVENT)	(16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
110-200 (45)	6.00E-06	NO FAIL (& PF)	1			1		0.000006										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000		0.00E+00		0.000				0.000	DAM-BIRNEY	114	0.075000	8.6
															BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000		0.00E+00			0.000				DAM-BIRNEY	114	0.075000	8.6
															BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000		0.00E+00				0.000			DAM-BIRNEY	114	0.075000	8.6
															BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000		0.00E+00					0.000		DAM-BIRNEY	114	0.075000	8.6
															BELOW BIRNEY	10032	0.000200	2.0
200-382 (100)	3.00E-06	NO FAIL (& PF)	0.85		3442.0	1		0.000002										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000	1480	0.00E+00	306	0.000				0.000	DAM-BIRNEY	114	0.075000	8.6
															BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000	1480	0.00E+00	306		0.000				DAM-BIRNEY	114	0.075000	8.6
															BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0500	F SPILLWAY		1.0000	1480	1.50E-07	306			0.000			DAM-BIRNEY	114	0.075000	8.6
															BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	1480	0.00E+00	306				0.000		DAM-BIRNEY	114	0.075000	8.6
															BELOW BIRNEY	10032	0.000200	2.0
>382 (>138)	1.00E-06	NO FAIL (& PF)	0.85		3447.2	1		0.000000										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000	1690	0.00E+00	310	0.000				0.000	DAM-BIRNEY	114	0.075000	8.6
															BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000	1690	0.00E+00	310		0.000				DAM-BIRNEY	114	0.075000	8.6
															BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0500	F SPILLWAY		1.0000	1680	5.00E-08	310			0.000			DAM-BIRNEY	114	0.075000	8.6
															BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.1000	F - BREACH		1.0000	1690	1.00E-07	310				0.000		DAM-BIRNEY	114	0.075000	8.6
															BELOW BIRNEY	10032	0.000200	2.0
							TOTAL	3.00E-07	TOTAL =	0.000	0.000	0.000	0.000					

Annual Risk Cost(Summer Flood Event)= 0.000

LOADING		SYSTEM RESPONSE			OUTCOME				ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12)	(13)	(14)	(15)	(16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
SEISMIC - (MAGNITUDE) M 0. - 5.5 (0 -.08g)	1.00E-02	NO FAIL (& PF)	1		3424.4	1		0.01		0								
		RES. LANDSLIDE	0	F - BREACH		0.0000	580	0.00E+00	273	0					DAM - BIRNEY BELOW BIRNEY	114 10032	0.150000 0.000200	17.1 2.0
		FOUNDAT LIQ	0.0000	F - BREACH		0.0000	580	0.00E+00	273	0					DAM - BIRNEY BELOW BIRNEY	114 10032	0.150000 0.000200	17.1 2.0
		EMB. DEFOR.	0.0000	F - BREACH		0.0000	560	0.00E+00	273	0					DAM - BIRNEY BELOW BIRNEY	114 10032	0.150000 0.000200	17.1 2.0
		CORE CRACK/PIPE	0.1000	F - BREACH		0.0000	580	0.00E+00	273	0					DAM - BIRNEY BELOW BIRNEY	114 10032	0.150000 0.000200	17.1 2.0
		OUTLET-RUPTURE	0.2500	F - BREACH		0.0000	580	0.00E+00	273	0					DAM - BIRNEY BELOW BIRNEY	114 10032	0.150000 0.000200	17.1 2.0
M>5.5 (>.08g)	1.00E-03	NO FAIL (& PF)	0.898			1		0.000988		0								
		RES. LANDSLIDE	0.001	F - BREACH		0.0000	560	0.00E+00	273	0					DAM - BIRNEY BELOW BIRNEY	114 10032	0.150000 0.000200	17.1 2.0
		FOUNDAT LIQ	0.0010	F - BREACH		1.0000	580	1.00E-08	273	0.000273					DAM - BIRNEY BELOW BIRNEY	114 10032	0.150000 0.000200	17.1 2.0
		EMB. DEFOR.	0.0000	F - BREACH		0.0000	580	0.00E+00	273	0					DAM - BIRNEY BELOW BIRNEY	114 10032	0.150000 0.000200	17.1 2.0
		CORE CRACK/PIPE	0.0000	F - BREACH		0.0000	580	0.00E+00	273	0					DAM - BIRNEY BELOW BIRNEY	114 10032	0.150000 0.000200	17.1 2.0
		OUTLET-RUPTURE	0.0000	F - BREACH		0.0000	560	0.00E+00	273	0					DAM - BIRNEY	114 10032	0.150000 0.000200	17.1 2.0
							TOTAL	1.00E-06	TOTAL	0.000273								

Annual Risk Cost (Seismic Event)= 0.000273

Tongue River Dam Risk Analysis — ALTERNATIVE B, SPILLWAY CAPACITY - 382,000 (100% PMF) Static Events

LOADING		SYSTEM RESPONSE			OUTCOME				ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12)	(13)	(14)	(15)	(16) POPULATION AT RISK	(17) EXPOSURE PROB	(18) EXPOSURE PROB	(18) LOSS OF LIFE PER EVENT
STATIC - FOUNDATION																		
	1.00E+00	EMB. DEFOR.	3.80E-05	F - BREACH	3424.4	1.0000	570	3.80E-05		0.000					DAM - BIRNEY	114	0.150000	17.1
									274	0.010					BELOW BIRNEY	10032	0.000200	2.0
									TOTAL =	0.010								
STATIC - PIPING EMBANKMENT																		
	1.00E+00	PIPING	1.20E-05	F - BREACH		1.0000	570	1.20E-05		0.000					DAM - BIRNEY	114	0.150000	17.1
									274	0.003					BELOW BIRNEY	10032	0.000200	2.0
									TOTAL =	0.003								
STATIC - SLOPE STABILITY																		
	1.00E+00	EMB. DEFOR.	2.80E-06	F - BREACH		1.0000	570	2.80E-06		0.000					DAM - BIRNEY	114	0.150000	17.1
									274	0.001					BELOW BIRNEY	10032	0.000200	2.0
									TOTAL =	0.001								
STATIC - PIPING OUTLET WORKS																		
	1.00E+00	PIPING/GATE F	1.80E-06	F - BREACH		1.0000	570	1.80E-06		0.000					DAM - BIRNEY	114	0.150000	17.1
									274	0.000					BELOW BIRNEY	10032	0.000200	2.0
									TOTAL =	0.000								
STATIC - LANDSLIDE INTO RESERVOIR																		
	1.00E-02	SEICHE	1.00E-03			1.0000									DAM - BIRNEY	114	0.150000	17.1
				F-BREACH		0.0000	570	0.00E+00	274	0.000					BELOW BIRNEY	10032	0.000200	2.0
							TOTAL	5.24E-05	TOTAL =	0.000								

Annual Risk Cost (Static Event)= 0.014357

ANNUAL RISK COST FOR LOADING EVENTS = 0.018
ANNUAL RISK COST FOR DAM REPLACEMENT = 0.009

ANNUAL RISK COST FOR ALTERNATIVE = 0.024 Million $

ALTERNATIVE 8, SPILLWAY CAPACITY - 382,000 (100% PMF)

LOSS-OF LIFE PROBABILITIES

TOTAL	LOSS-OF-LIFE	PROBABILITY
	0 TO 15	3.30E-06
	0 TO 25	5.67E-05
	MORE THAN 25	0.00E+00

HYDROLOGIC EVENT	LOSS-OF-LIFE	PROBABILITY
	0 TO 15	3.30E-06
	MORE THAN 15	0.00E+00

SEISMIC EVENT	LOSS-OF-LIFE	PROBABILITY
	0 TO 25	1.00E-06
	MORE THAN 25	0.00E+00

STATIC EVENT		PROBABILITY
	0 TO 25	5.24E-05
	MORE THAN 25	0.00E+00

LOADING		SYSTEM RESPONSE			OUTCOME				ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12) ANNUAL RISK COST ($*10**6)	(13) ANNUAL RISK COST ($*10**6)	(14) ANNUAL RISK COST ($*10**6)	(15) (TOTAL/ EVENT)	(16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
HYDROLOGIC - SPRING FLOOD (PEAK INFLOW IN K. CFS)																		
0-10 (0-7)	8.75E-01	NO FAIL (& PF)	1			1		0.975										
		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
10-15 (7-11)	1.80E-02	NO FAIL (& PF)	1			1		0.018										
		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
15-20 (11-18)	4.00E-03	NO FAIL (& PF)	1			1		0.004										
		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
20-25 (18-21)	8.00E-04	NO FAIL (& PF)	1			1		0.0008										
		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0

LOADING (1) EVENT TYPE	(2) EVENT PROB	SYSTEM RESPONSE (3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	OUTCOME (6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	ECONOMIC DAMAGE (10) PER EVENT (\$*10**6)	(11) (\$*10**6)	ANNUAL RISK COST (12) (\$*10**6)	(13) (\$*10**6)	(14) (\$*10**6)	(15) (TOTAL/ EVENT)	THREAT TO LIFE (16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
26-30 (21-25)	8.00E-04	NO FAIL (& PF)	1			1		0.0008										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
30-50 (25-43)	8.00E-04	NO FAIL (& PF)	1			1		0.0008										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
50-80 (43-70)	3.00E-04	NO FAIL (& PF)	1			1		0.0003										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
80-110 (70-101)	1.80E-04	NO FAIL (& PF)	0.95		3442.1	1		0.000171										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000	1370	0.00E+00	303	0.000				0.003	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000	1370	0.00E+00	303		0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0500	F SPILLWAY		1.0000	1370	9.00E-08	303			0.003			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	1370	0.00E+00	303				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0

LOADING		SYSTEM RESPONSE			OUTCOME				ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12) ANNUAL RISK COST ($*10**6)	(13) ANNUAL RISK COST ($*10**6)	(14) ANNUAL RISK COST ($*10**6)	(15) (TOTAL/ EVENT)	(16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
110-200	8.00E-05	NO FAIL (& PF)	0.5		3444.5	1		0.00004										
(101-198)		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000	1840	0.00E+00						0.012	DAM-BIRNEY	114	0.075000	8.5
									309.5	0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000	1840	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									309.5		0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.1000															
				F SPILLWAY		1.0000	1840	8.00E-06							DAM-BIRNEY	114	0.075000	8.5
									309.5			0.002			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.4000															
				F - BREACH		1.0000	1840	3.20E-05							DAM-BIRNEY	114	0.075000	8.5
									309.5				0.010		BELOW BIRNEY	10032	0.000200	2.0
200-382	3.00E-06	NO FAIL (& PF)	0.05		3450.5	1		0.000001										
(198-379)		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000	1820	0.00E+00						0.009	DAM-BIRNEY	114	0.075000	8.5
									313	0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000	1820	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									313		0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.1000															
				F SPILLWAY		1.0000	1920	3.00E-06							DAM-BIRNEY	114	0.075000	8.5
									313			0.001			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.8500															
				F - BREACH		1.0000	1920	2.55E-05							DAM-BIRNEY	114	0.075000	8.5
									313				0.008		BELOW BIRNEY	10032	0.000200	2.0
>382	1.00E-05	NO FAIL (& PF)	0		3454.3	1		0										
(>379)		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000	2520	0.00E+00						0.003	DAM-BIRNEY	114	0.075000	8.5
									320	0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000	2520	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									320		0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.1500															
				F SPILLWAY		1.0000	2520	1.50E-06							DAM-BIRNEY	114	0.075000	8.5
									320			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.8500															
				F - BREACH		1.0000	2520	8.50E-06							DAM-BIRNEY	114	0.075000	8.5
									320				0.003		BELOW BIRNEY	10032	0.000200	2.0
							TOTAL	8.75E-05	TOTAL =	0.000	0.000	0.007	0.021					

Annual Risk Cost (Spring Flood Event)= 0.027

LOADING [1] EVENT TYPE	[2] EVENT PROB	SYSTEM RESPONSE [3] RESPONSE TYPE	[4] RESPONSE PROB	OUTCOME [5] OUTCOME TYPE	[6] RESERVOIR STAGE (FT MSL)	[7] OUTCOME PROB	[8] BREACH PEAK FLOW (K CFS)	[9] PATHWAY PROB.	ECONOMIC DAMAGE [10] PER EVENT ($*10**6)	[11] ($*10**6)	[12] ANNUAL RISK COST ($*10**6)	[13] ($*10**6)	[14] ($*10**6)	[15] (TOTAL/ EVENT)	THREAT TO LIFE [16] POPULATION AT RISK	[17] POPULATION AT RISK	[18] EXPOSURE PROB	[19] LOSS OF LIFE PER EVENT
HYDROLOGIC - SUMMER FLOOD (INFLOWS IN K. CFS)																		
0-10	0.89955	NO FAIL (& PF)	1			1		0.89955										
(0-4)		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000		0.00E+00						0.000	DAM-BIRNEY	114	0.075000	8.5
										0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
											0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
												0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
													0.000		BELOW BIRNEY	10032	0.000200	2.0
10-15	1.50E-04	NO FAIL (& PF)	1			1		0.00015										
(4-5)		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000		0.00E+00						0.000	DAM-BIRNEY	114	0.075000	8.5
										0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
											0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
												0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
													0.000		BELOW BIRNEY	10032	0.000200	2.0
15-20	1.00E-04	NO FAIL (& PF)	1			1		0.0001										
(5-5)		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000		0.00E+00						0.000	DAM-BIRNEY	114	0.075000	8.5
										0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
											0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
												0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
													0.000		BELOW BIRNEY	10032	0.000200	2.0
20-25	8.00E-05	NO FAIL (& PF)	1			1		0.00008										
(5-6)		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000		0.00E+00						0.000	DAM-BIRNEY	114	0.075000	8.5
										0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
											0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
												0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
													0.000		BELOW BIRNEY	10032	0.000200	2.0

LOADING		SYSTEM RESPONSE		OUTCOME					ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12) ANNUAL RISK COST ($*10**6)	(13) ANNUAL RISK COST ($*10**6)	(14) ANNUAL RISK COST ($*10**6)	(15) (TOTAL/ EVENT)	(16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
25-30	3.00E-05	NO FAIL (& PF)	1			1		0.00003										
(6-7)		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000		0.00E+00						0.000	DAM-BIRNEY	114	0.075000	8.5
										0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
											0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
												0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
													0.000		BELOW BIRNEY	10032	0.000200	2.0
30-50	4.00E-05	NO FAIL (& PF)	1			1		0.00004										
(7-10)		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000		0.00E+00						0.000	DAM-BIRNEY	114	0.075000	8.5
										0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
											0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
												0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
													0.000		BELOW BIRNEY	10032	0.000200	2.0
50-80	3.00E-05	NO FAIL (& PF)	1			1		0.00003										
(10-18)		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000		0.00E+00						0.000	DAM-BIRNEY	114	0.075000	8.5
										0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
											0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
												0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
													0.000		BELOW BIRNEY	10032	0.000200	2.0
80-110	1.00E-05	NO FAIL (& PF)	0.95		3430.4	1		0.000009										
(18-25)		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000	990	0.00E+00						0.000	DAM-BIRNEY	114	0.075000	8.5
									293	0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000	990	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									293		0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0500															
				F SPILLWAY		1.0000	990	5.00E-07							DAM-BIRNEY	114	0.075000	8.5
									293			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	990	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									293				0.000		BELOW BIRNEY	10032	0.000200	2.0

LOADING		SYSTEM RESPONSE		OUTCOME					ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12) ANNUAL RISK COST ($*10**6)	(13) ANNUAL RISK COST ($*10**6)	(14) ANNUAL RISK COST ($*10**6)	(15) (TOTAL/ EVENT)	(16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
110-200 (25-53)	6.00E-06	NO FAIL (& PF)	0.5		3433.6	1		0.000003										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000	1170	0.00E+00	296	0.000				0.001	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000	1170	0.00E+00	298		0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.1000	F SPILLWAY		1.0000	1170	6.00E-07	298			0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.4000	F - BREACH		1.0000	1170	2.40E-06	296				0.001		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
200-382 (53-122)	3.00E-06	NO FAIL (& PF)	0.05		3440.1	1		0.000000										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000	1400	0.00E+00	304	0.000				0.001	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000	1400	0.00E+00	304		0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.1000	F SPILLWAY		1.0000	1400	3.00E-07	304			0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.8500	F - BREACH		1.0000	1400	2.55E-06	304				0.001		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
>382 (>122)	1.00E-06	NO FAIL (& PF)	0		3448.2	1		0										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000	1800	0.00E+00	309.5	0.000				0.000	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000	1800	0.00E+00	309.5		0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.1500	F SPILLWAY		1.0000	1800	1.50E-07	309.5			0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.8500	F - BREACH		1.0000	1800	8.50E-07	309.5				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
							TOTAL	7.35E-06	TOTAL =	0.000	0.000	0.000	0.002					

Annual Risk Cost (Summer Flood Event) = 0.002

LOADING		SYSTEM RESPONSE			OUTCOME				ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12)	(13)	(14)	(15)	(16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
SEISMIC - (MAGNITUDE)																		
M 0. - 5.5	1.00E-02	NO FAIL (& PF)	1		3424.4	1		0.01		0								
(0 -.08g)		RES. LANDSLIDE	0															
				F - BREACH		0.0000	560	0.00E+00							DAM - BIRNEY	114	0.150000	17.1
									273	0					BELOW BIRNEY	10032	0.000200	2.0
		FOUNDAT LIQ	0.0000															
				F - BREACH		0.0000	560	0.00E+00							DAM - BIRNEY	114	0.150000	17.1
									273	0					BELOW BIRNEY	10032	0.000200	2.0
		EMB. DEFOR.	0.0000															
				F - BREACH		0.0000	560	0.00E+00							DAM - BIRNEY	114	0.150000	17.1
									273	0					BELOW BIRNEY	10032	0.000200	2.0
		CORE CRACK/PIPE	0.1000															
				F - BREACH		0.0000	560	0.00E+00							DAM - BIRNEY	114	0.150000	17.1
									273	0					BELOW BIRNEY	10032	0.000200	2.0
		OUTLET-RUPTURE	0.2500															
				F - BREACH		0.0000	560	0.00E+00							DAM - BIRNEY	114	0.150000	17.1
									273	0					BELOW BIRNEY	10032	0.000200	2.0
M>5.5	1.00E-03	NO FAIL (& PF)	0.988			1		0.000988		0								
(>.08g)		RES. LANDSLIDE	0.001															
				F - BREACH		0.0000	560	0.00E+00							DAM - BIRNEY	114	0.150000	17.1
									273	0					BELOW BIRNEY	10032	0.000200	2.0
		FOUNDAT LIQ	0.0010															
				F - BREACH		1.0000	560	1.00E-08							DAM - BIRNEY	114	0.150000	17.1
									273	0					BELOW BIRNEY	10032	0.000200	2.0
		EMB. DEFOR.	0.0000															
				F - BREACH		0.0000	560	0.00E+00							DAM - BIRNEY	114	0.150000	17.1
									273	0					BELOW BIRNEY	10032	0.000200	2.0
		CORE CRACK/PIPE	0.0000															
				F - BREACH		0.0000	560	0.00E+00							DAM - BIRNEY	114	0.150000	17.1
									273	0					BELOW BIRNEY	10032	0.000200	2.0
		OUTLET-RUPTURE	0.0000															
				F - BREACH		0.0000	560	0.00E+00							DAM - BIRNEY	114	0.150000	17.1
									273	0						10032	0.000200	2.0
							TOTAL	1.00E-06	TOTAL	0.000273								

Annual Risk Cost (Seismic Event)= 0.000273

Tongue River Dam Risk Analysis — ALTERNATIVE C, SPILLWAY CAPACITY - 103,400 (27% PMF) Static Events

LOADING		SYSTEM RESPONSE			OUTCOME				ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12)	(13)	(14)	(15)	(16) POPULATION AT RISK	(17) EXPOSURE PROB	(18) EXPOSURE PROB	(18) LOSS OF LIFE PER EVENT
STATIC - FOUNDATION																		
	1.00E+00	EMB. DEFOR.	3.80E-05	F - BREACH	3424.4	1.0000	580	3.80E-05		0.000					DAM - BIRNEY	114	0.150000	17.1
									273	0.010					BELOW BIRNEY	10032	0.000200	2.0
									TOTAL =	0.010								
STATIC - PIPING EMBANKMENT																		
	1.00E+00	PIPING	1.20E-05	F - BREACH		1.0000	560	1.20E-05		0.000					DAM - BIRNEY	114	0.150000	17.1
									273	0.003					BELOW BIRNEY	10032	0.000200	2.0
									TOTAL =	0.003								
STATIC - SLOPE STABILITY																		
	1.00E+00	EMB. DEFOR.	2.80E-06	F - BREACH		1.0000	580	2.80E-06		0.000					DAM - BIRNEY	114	0.150000	17.1
									273	0.001					BELOW BIRNEY	10032	0.000200	2.0
									TOTAL =	0.001								
STATIC - PIPING OUTLET WORKS																		
	1.00E+00	PIPING/GATE F	1.80E-06	F - BREACH		1.0000	580	1.80E-06		0.000					DAM - BIRNEY	114	0.150000	17.1
									273	0.000					BELOW BIRNEY	10032	0.000200	2.0
									TOTAL =	0.000								
STATIC - LANDSLIDE INTO RESERVOIR																		
	1.00E-02	SEICHE	1.00E-03	F-BREACH		1.0000									DAM - BIRNEY	114	0.150000	17.1
						0.0000	560	0.00E+00	273	0.000					BELOW BIRNEY	10032	0.000200	2.0
							TOTAL	5.24E-05	TOTAL =	0.000								

Annual Risk Cost (Static Event)= 0.014305

ANNUAL RISK COST FOR LOADING EVENTS = 0.044
ANNUAL RISK COST FOR DAM REPLACEMENT = 0.022

ANNUAL RISK COST FOR ALTERNATIVE = 0.066 Million $

ALTERNATIVE C, SPILLWAY CAPACITY - 103,400 (27% PMF)

LOSS-OF LIFE PROBABILITIES

TOTAL	LOSS-OF-LIFE			PROBABILITY
	0	TO	15	9.49E-05
	0	TO	25	1.48E-04
	MORE THAN		25	0.00E+00

HYDROLOGIC EVENT	LOSS-OF-LIFE			PROBABILITY
	0	TO	15	9.49E-05
	MORE THAN		15	0.00E+00

SEISMIC EVENT	LOSS-OF-LIFE			PROBABILITY
	0	TO	25	1.00E-06
	MORE THAN		25	0.00E+00

STATIC EVENT	LOSS-OF-LIFE			PROBABILITY
	0	TO	25	5.24E-05
	MORE THAN		25	0.00E+00

LOADING		SYSTEM RESPONSE			OUTCOME				ECONOMIC DAMAGE					THREAT TO LIFE			
EVENT TYPE	EVENT PROB	RESPONSE TYPE	RESPONSE PROB	OUTCOME TYPE	RESERVOIR STAGE (FT MSL)	OUTCOME PROB	BREACH PEAK FLOW (K CFS)	PATHWAY PROB.	PER EVENT ($*10**6)	ANNUAL RISK COST ($*10**6)	($*10**6)	($*10**6)	($*10**6) (TOTAL/ EVENT)	POPULATION AT RISK	POPULATION AT RISK	EXPOSURE PROB	LOSS OF LIFE PER EVENT
HYDROLOGIC - SPRING FLOOD (PEAK INFLOW IN K. CFS)																	
0-10 (0-7)	9.75E-01	NO FAIL (& PF)	1			1		0.975									
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000		0.00E+00						DAM-BIRNEY	114	0.075000	8.5
														BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000		0.00E+00						DAM-BIRNEY	114	0.075000	8.5
														BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000		0.00E+00						DAM-BIRNEY	114	0.075000	8.5
														BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000		0.00E+00						DAM-BIRNEY	114	0.075000	8.5
														BELOW BIRNEY	10032	0.000200	2.0
10-15 (7-11)	1.80E-02	NO FAIL (& PF)	1			1		0.018									
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000		0.00E+00						DAM-BIRNEY	114	0.075000	8.5
														BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000		0.00E+00						DAM-BIRNEY	114	0.075000	8.5
														BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000		0.00E+00						DAM-BIRNEY	114	0.075000	8.5
														BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000		0.00E+00						DAM-BIRNEY	114	0.075000	8.5
														BELOW BIRNEY	10032	0.000200	2.0
15-20 (11-16)	4.00E-03	NO FAIL (& PF)	1			1		0.004									
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000		0.00E+00						DAM-BIRNEY	114	0.075000	8.5
														BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000		0.00E+00						DAM-BIRNEY	114	0.075000	8.5
														BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000		0.00E+00						DAM-BIRNEY	114	0.075000	8.5
														BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000		0.00E+00						DAM-BIRNEY	114	0.075000	8.5
														BELOW BIRNEY	10032	0.000200	2.0
20-25 (16-20)	8.00E-04	NO FAIL (& PF)	1			1		0.0008									
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000		0.00E+00						DAM-BIRNEY	114	0.075000	8.5
														BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000		0.00E+00						DAM-BIRNEY	114	0.075000	8.5
														BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000		0.00E+00						DAM-BIRNEY	114	0.075000	8.5
														BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000		0.00E+00						DAM-BIRNEY	114	0.075000	8.5
														BELOW BIRNEY	10032	0.000200	2.0

LOADING (1) EVENT TYPE	(2) EVENT PROB	SYSTEM RESPONSE (3) RESPONSE TYPE	(4) RESPONSE PROB	OUTCOME (5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	ECONOMIC DAMAGE (10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12) ($*10**6)	(13) ($*10**6)	(14) ($*10**6)	(15) (TOTAL/EVENT)	THREAT TO LIFE (16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
25-30 (20-24)	8.00E-04	NO FAIL (& PF)	1			1		0.0008										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
30-60 (24-42)	8.00E-04	NO FAIL (& PF)	1			1		0.0008										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000		0.00E+00							DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
60-80 (42-68)	3.00E-04	NO FAIL (& PF)	0.8		3438.5	1		0.00027						0.080				
		SPILL CREST F	0.0500	F - SPILLWAY		1.0000	1130	1.50E-05	287	0.080					DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0500	F STILL B.		1.0000	1130	1.50E-05	297		0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000	1130	0.00E+00	297			0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	1130	0.00E+00	287				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
80-110 (68-103)	1.80E-04	NO FAIL (& PF)	0.75		3440.3	1		0.000135						0.000				
		SPILL CREST F	0.1000	F - SPILLWAY		1.0000	1330	1.80E-05	302	0.005				0.014	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.1000	F STILL B.		1.0000	1330	1.80E-05	302		0.005				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0500	F SPILLWAY		1.0000	1330	9.00E-06	302			0.003			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	1330	0.00E+00	302				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0

LOADING		SYSTEM RESPONSE		OUTCOME					ECONOMIC DAMAGE						THREAT TO LIFE			
[1] EVENT TYPE	[2] EVENT PROB	[3] RESPONSE TYPE	[4] RESPONSE PROB	[5] OUTCOME TYPE	[6] RESERVOIR STAGE (FT MSL)	[7] OUTCOME PROB	[8] BREACH PEAK FLOW (K CFS)	[9] PATHWAY PROB.	[10] PER EVENT ($*10**8)	[11] ANNUAL RISK COST ($*10**8)	[12] ANNUAL RISK COST ($*10**8)	[13] ANNUAL RISK COST ($*10**8)	[14] ANNUAL RISK COST ($*10**8)	[15] (TOTAL/EVENT)	[18] POPULATION AT RISK	[17] POPULATION AT RISK	[18] EXPOSURE PROB	[19] LOSS OF LIFE PER EVENT
110-200 (103-198)	8.00E-05	NO FAIL (& PF)	0.2		3443.1	1		0.000018										
		SPILL CREST F	0.1500	F - SPILLWAY		1.0000	1525	1.20E-05						0.020	DAM-BIRNEY	114	0.075000	8.5
									307	0.004					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.1500	F STILL B.		1.0000	1525	1.20E-05							DAM-BIRNEY	114	0.075000	8.5
									307		0.004				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.1000	F SPILLWAY		1.0000	1525	8.00E-08							DAM-BIRNEY	114	0.075000	8.5
									307			0.002			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.4000	F - BREACH		1.0000	1525	3.20E-05							DAM-BIRNEY	114	0.075000	8.5
									307				0.010		BELOW BIRNEY	10032	0.000200	2.0
200-382 (198-378)	3.00E-06	NO FAIL (& PF)	0		3444.4	1		0										
		SPILL CREST F	0.1500	F - SPILLWAY		1.0000	1845	4.50E-08						0.009	DAM-BIRNEY	114	0.075000	8.5
									309.5	0.001					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.1500	F STILL B.		1.0000	1845	4.50E-08							DAM-BIRNEY	114	0.075000	8.5
									309.5		0.001				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.1000	F SPILLWAY		1.0000	1845	3.00E-06							DAM-BIRNEY	114	0.075000	8.5
									309.5			0.001			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.8000	F - BREACH		1.0000	1845	1.80E-05							DAM-BIRNEY	114	0.075000	8.5
									309.5				0.006		BELOW BIRNEY	10032	0.000200	2.0
>382 (>379)	1.00E-06	NO FAIL (& PF)	0		3444.9	1		0										
		SPILL CREST F	0.1500	F - SPILLWAY		1.0000	1730	1.50E-06						0.003	DAM-BIRNEY	114	0.075000	8.5
									310.5	0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.1500	F STILL B.		1.0000	1730	1.50E-06							DAM-BIRNEY	114	0.075000	8.5
									310.5		0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.1000	F SPILLWAY		1.0000	1730	1.00E-06							DAM-BIRNEY	114	0.075000	8.5
									310.5			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.8000	F - BREACH		1.0000	1730	8.00E-06							DAM-BIRNEY	114	0.075000	8.5
									310.5				0.002		BELOW BIRNEY	10032	0.000200	2.0
							TOTAL	1.79E-04	TOTAL =	0.091	0.011	0.008	0.017					

Annual Risk Cost(Spring Flood Event)= 0.128

LOADING		SYSTEM RESPONSE			OUTCOME				ECONOMIC DAMAGE	THREAT TO LIFE			
EVENT TYPE	EVENT PROB	RESPONSE TYPE	RESPONSE PROB	OUTCOME TYPE	RESERVOIR STAGE (FT MSL)	OUTCOME PROB	BREACH PEAK FLOW (K CFS)	PATHWAY PROB.	PER EVENT ($*10**6)	POPULATION AT RISK	POPULATION AT RISK	EXPOSURE PROB	LOSS OF LIFE PER EVENT
HYDROLOGIC - SUMMER FLOOD (INFLOWS IN K. CFS)													
0-10 (2)	0.99955	NO FAIL (& PF)	1			1		0.99955					
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000		0.00E+00		DAM-BIRNEY	114	0.075000	8.5
										BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000		0.00E+00		DAM-BIRNEY	114	0.075000	8.5
										BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000		0.00E+00		DAM-BIRNEY	114	0.075000	8.5
										BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000		0.00E+00		DAM-BIRNEY	114	0.075000	8.5
										BELOW BIRNEY	10032	0.000200	2.0
10-15 (4.5)	1.50E-04	NO FAIL (& PF)	1			1		0.00015					
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000		0.00E+00		DAM-BIRNEY	114	0.075000	8.5
										BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000		0.00E+00		DAM-BIRNEY	114	0.075000	8.5
										BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000		0.00E+00		DAM-BIRNEY	114	0.075000	8.5
										BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000		0.00E+00		DAM-BIRNEY	114	0.075000	8.5
										BELOW BIRNEY	10032	0.000200	2.0
15-20 (5)	1.00E-04	NO FAIL (& PF)	1			1		0.0001					
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000		0.00E+00		DAM-BIRNEY	114	0.075000	8.5
										BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000		0.00E+00		DAM-BIRNEY	114	0.075000	8.5
										BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000		0.00E+00		DAM-BIRNEY	114	0.075000	8.5
										BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000		0.00E+00		DAM-BIRNEY	114	0.075000	8.5
										BELOW BIRNEY	10032	0.000200	2.0
20-25 (5.5)	8.00E-05	NO FAIL (& PF)	1			1		0.00008					
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000		0.00E+00		DAM-BIRNEY	114	0.075000	8.5
										BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000		0.00E+00		DAM-BIRNEY	114	0.075000	8.5
										BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000		0.00E+00		DAM-BIRNEY	114	0.075000	8.5
										BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000		0.00E+00		DAM-BIRNEY	114	0.075000	8.5
										BELOW BIRNEY	10032	0.000200	2.0

LOADING		SYSTEM RESPONSE		OUTCOME					ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12) ($*10**6)	(13) ($*10**6)	(14) ($*10**6)	(15) (TOTAL/ EVENT)	(16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
25-30 (8.5)	4.00E-05	NO FAIL (& PF)	1			1		0.00004										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
															BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
															BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
															BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
															BELOW BIRNEY	10032	0.000200	2.0
30-50 (8.5)	4.00E-05	NO FAIL (& PF)	1			1		0.00004										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
															BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
															BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
															BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000		0.00E+00							DAM-BIRNEY	114	0.075000	8.5
															BELOW BIRNEY	10032	0.000200	2.0
50-80 (9)	3.00E-05	NO FAIL (& PF)	0.9		3428.5	1		0.000027										
		SPILL CREST F	0.0500	F - SPILLWAY		1.0000	845	1.50E-08						0.001	DAM-BIRNEY	114	0.075000	8.5
									289	0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0500	F STILL B.		1.0000	845	1.50E-08							DAM-BIRNEY	114	0.075000	8.5
									289		0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000	845	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									289			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	845	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									289				0.000		BELOW BIRNEY	10032	0.000200	2.0
80-110 (18.5)	1.00E-05	NO FAIL (& PF)	0.75		3430.4	1		0.000007										
		SPILL CREST F	0.1000	F - SPILLWAY		1.0000	840	1.00E-08						0.001	DAM-BIRNEY	114	0.075000	8.5
									292	0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.1000	F STILL B.		1.0000	940	1.00E-08							DAM-BIRNEY	114	0.075000	8.5
									292		0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0500	F SPILLWAY		1.0000	840	5.00E-07							DAM-BIRNEY	114	0.075000	8.5
									292			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	890	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									292				0.000		BELOW BIRNEY	10032	0.000200	2.0

LOADING		SYSTEM RESPONSE			OUTCOME				ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12) ANNUAL RISK COST ($*10**6)	(13) ANNUAL RISK COST ($*10**6)	(14) ANNUAL RISK COST ($*10**6)	(15) (TOTAL/ EVENT)	(16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
110-200 (38.5)	8.00E-08	NO FAIL (& PF)	0.2		3433.8	1		0.000001										
		SPILL CREST F	0.1500	F - SPILLWAY		1.0000	1100	8.00E-07	298	0.000				0.001	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.1500	F STILL B.		1.0000	1100	9.00E-07	298		0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.1000	F SPILLWAY		1.0000	1100	6.00E-07	298			0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.4000	F - BREACH		1.0000	1100	2.40E-06	288				0.001		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
200-382 (87)	3.00E-08	NO FAIL (& PF)	0		3440.1	1		0										
		SPILL CREST F	0.1500	F - SPILLWAY		1.0000	1335	4.50E-07	302	0.000				0.001	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.1500	F STILL B.		1.0000	1335	4.50E-07	302		0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.1000	F SPILLWAY		1.0000	1335	3.00E-07	302			0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.6000	F - BREACH		1.0000	1335	1.80E-06	302				0.001		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
>382 (>122)	1.00E-08	NO FAIL (& PF)	0		3445.7	1		0										
		SPILL CREST F	0.1500	F - SPILLWAY		1.0000	1560	1.50E-07	308	0.000				0.000	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.1500	F STILL B.		1.0000	1550	1.50E-07	308		0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.1000	F SPILLWAY		1.0000	1550	1.00E-07	308			0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.6000	F - BREACH		1.0000	1550	6.00E-07	308				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
							TOTAL	1.43E-05	TOTAL =	0.001	0.001	0.000	0.001					

Annual Risk Cost(Summer Flood Event)= 0.003

Tongue River Dam Risk Analysis — ALTERNATIVE D, SPILLWAY CAPACITY - 60,000 (16% PMF) Seismic Event

LOADING		SYSTEM RESPONSE			OUTCOME				ECONOMIC DAMAGE		THREAT TO LIFE			
EVENT TYPE	EVENT PROB	RESPONSE TYPE	RESPONSE PROB	OUTCOME TYPE	RESERVOIR STAGE (FT MSL)	OUTCOME PROB	BREACH PEAK FLOW (K CFS)	PATHWAY PROB.	PER EVENT ($*10**6)	ANNUAL RISK COST ($*10**6)	POPULATION AT RISK	POPULATION AT RISK	EXPOSURE PROB	
SEISMIC - (MAGNITUDE)														
M 0. - 5.5 (0 -.08g)	1.00E-02	NO FAIL (& PF)	1		3424.4	1		0.01		0				
		RES. LANDSLIDE	0											
				F - BREACH		0.0000	560	0.00E+00			DAM - BIRNEY	114	0.150000	17.1
									273	0	BELOW BIRNEY	10032	0.000200	2.0
		FOUNDAT LIQ	0.0000											
				F - BREACH		0.0000	560	0.00E+00			DAM - BIRNEY	114	0.150000	17.1
									273	0	BELOW BIRNEY	10032	0.000200	2.0
		EMB. DEFOR.	0.0000											
				F - BREACH		0.0000	560	0.00E+00			DAM - BIRNEY	114	0.150000	17.1
									273	0	BELOW BIRNEY	10032	0.000200	2.0
		CORE CRACK/PIPE	0.1000											
				F - BREACH		0.0000	560	0.00E+00			DAM - BIRNEY	114	0.150000	17.1
									273	0	BELOW BIRNEY	10032	0.000200	2.0
		OUTLET-RUPTURE	0.2500											
				F - BREACH		0.0000	560	0.00E+00			DAM - BIRNEY	114	0.150000	17.1
									273	0	BELOW BIRNEY	10032	0.000200	2.0
M>5.5 (>.08g)	1.00E-03	NO FAIL (& PF)	0.998			1		0.000998		0				
		RES. LANDSLIDE	0.001											
				F - BREACH		0.0000	560	0.00E+00			DAM - BIRNEY	114	0.150000	17.1
									273	0	BELOW BIRNEY	10032	0.000200	2.0
		FOUNDAT LIQ	0.0010											
				F - BREACH		1.0000	560	1.00E-06			DAM - BIRNEY	114	0.150000	17.1
									273	0.000273	BELOW BIRNEY	10032	0.000200	2.0
		EMB. DEFOR.	0.0000											
				F - BREACH		0.0000	560	0.00E+00			DAM - BIRNEY	114	0.150000	17.1
									273	0	BELOW BIRNEY	10032	0.000200	2.0
		CORE CRACK/PIPE	0.0000											
				F - BREACH		0.0000	560	0.00E+00			DAM - BIRNEY	114	0.150000	17.1
									273	0	BELOW BIRNEY	10032	0.000200	2.0
		OUTLET-RUPTURE	0.0000											
				F - BREACH		0.0000	560	0.00E+00			DAM - BIRNEY	114	0.150000	17.1
									273	0	BELOW BIRNEY	10032	0.000200	2.0
							TOTAL	1.00E-06	TOTAL	0.000273				

Annual Risk Cost(Seismic Event)= 0.000273

Tongue River Dam Risk Analysis — ALTERNATIVE D, SPILLWAY CAPACITY - 80,000 (16% PMF)

Static Events

LOADING		SYSTEM RESPONSE		OUTCOME					ECONOMIC DAMAGE		THREAT TO LIFE			
EVENT TYPE	EVENT PROB	RESPONSE TYPE	RESPONSE PROB	OUTCOME TYPE	RESERVOIR STAGE (FT MSL)	OUTCOME PROB	BREACH PEAK FLOW (K CFS)	PATHWAY PROB.	PER EVENT ($*10**6)	ANNUAL RISK COST ($*10**6)	POPULATION AT RISK	EXPOSURE PROB	EXPOSURE PROB	
STATIC - FOUNDATION														
	1.00E+00	EMB. DEFOR.	3.80E-05	F - BREACH	3424.4	1.0000	580	3.80E-05		0.000	DAM - BIRNEY	114	0.150000	17.1
									273	0.010	BELOW BIRNEY	10032	0.000200	2.0
									TOTAL =	0.010				
STATIC - PIPING EMBANKMENT														
	1.00E+00	PIPING	1.20E-05	F - BREACH		1.0000	580	1.20E-05		0.000	DAM - BIRNEY	114	0.150000	17.1
									273	0.003	BELOW BIRNEY	10032	0.000200	2.0
									TOTAL =	0.003				
STATIC - SLOPE STABILITY														
	1.00E+00	EMB. DEFOR.	2.80E-06	F - BREACH		1.0000	580	2.80E-06		0.000	DAM - BIRNEY	114	0.150000	17.1
									273	0.001	BELOW BIRNEY	10032	0.000200	2.0
									TOTAL =	0.001				
STATIC - PIPING OUTLET WORKS														
	1.00E+00	PIPING/GATE F	1.80E-08	F - BREACH		1.0000	580	1.80E-08		0.000	DAM - BIRNEY	114	0.150000	17.1
									273	0.000	BELOW BIRNEY	10032	0.000200	2.0
									TOTAL =	0.000				
STATIC - LANDSLIDE INTO RESERVOIR														
	1.00E-03	SEICHE	1.00E+00			1.0000					DAM - BIRNEY	114	0.150000	17.1
				F-BREACH		0.0000	580	0.00E+00		0.000	BELOW BIRNEY	10032	0.000200	2.0
							TOTAL	5.24E-05	TOTAL =	0.000				

Annual Risk Cost(Static Event)= 0.014305

ANNUAL RISK COST FOR LOADING EVENTS = 0.143
ANNUAL RISK COST FOR DAM REPLACEMENT = 0.037

ANNUAL RISK COST FOR ALTERNATIVE = 0.180 Million $

ALTERNATIVE D, SPILLWAY CAPACITY - 60,000 (16% PMF)

LOSS-OF LIFE PROBABILITIES

TOTAL	LOSS-OF-LIFE	PROBABILITY
	0 TO 15	1.93E-04
	0 TO 25	5.34E-05
	MORE THAN 25	0.00E+00

HYDROLOGIC EVENT	LOSS-OF-LIFE	PROBABILITY
	0 TO 15	1.93E-04
	MORE THAN 15	0.00E+00

SEISMIC EVENT	LOSS-OF-LIFE	PROBABILITY
	0 TO 25	1.00E-06
	MORE THAN 25	0.00E+00

STATIC EVENT	LOSS-OF-LIFE	PROBABILITY
	0 TO 25	5.24E-05
	MORE THAN 25	0.00E+00

LOADING		SYSTEM RESPONSE		OUTCOME					ECONOMIC DAMAGE						THREAT TO LIFE			
EVENT TYPE	EVENT PROB	RESPONSE TYPE	RESPONSE PROB	OUTCOME TYPE	RESERVOIR STAGE (FT MSL)	OUTCOME PROB	BREACH PEAK FLOW (K CFS)	PATHWAY PROB.	PER EVENT ($*10**6)	ANNUAL RISK COST ($*10**6)	($*10**6)	($*10**6)	($*10**6)	(TOTAL/ EVENT)	POPULATION AT RISK	POPULATION AT RISK	EXPOSURE PROB	LOSS OF LIFE PER EVENT
HYDROLOGIC - SPRING FLOOD (PEAK INFLOW IN K. CFS)																		
0-10 (5)	9.75E-01	NO FAIL (& PF)	1			1		0.975										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000	5	0.00E+00	0	0.000				0.000	DAM-BIRNEY	114	0.075000	8.5
															BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000	5	0.00E+00	0		0.000				DAM-BIRNEY	114	0.075000	8.5
															BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000	5	0.00E+00	0			0.000			DAM-BIRNEY	114	0.075000	8.5
															BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	5	0.00E+00	0				0.000		DAM-BIRNEY	114	0.075000	8.5
															BELOW BIRNEY	10032	0.000200	2.0
10-15 (12.5)	1.80E-02	NO FAIL (& PF)	1			1		0.018										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000	12.5	0.00E+00	0	0.000				0.000	DAM-BIRNEY	114	0.075000	8.5
															BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000	12.5	0.00E+00	0		0.000				DAM-BIRNEY	114	0.075000	8.5
															BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000	12.5	0.00E+00	0			0.000			DAM-BIRNEY	114	0.075000	8.5
															BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	12.5	0.00E+00	0				0.000		DAM-BIRNEY	114	0.075000	8.5
															BELOW BIRNEY	10032	0.000200	2.0
15-20 (17.5)	4.00E-03	NO FAIL (& PF)	1			1		0.004										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000	17.5	0.00E+00	0	0.000				0.000	DAM-BIRNEY	114	0.075000	8.5
															BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000	17.5	0.00E+00	0		0.000				DAM-BIRNEY	114	0.075000	8.5
															BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000	17.5	0.00E+00	0			0.000			DAM-BIRNEY	114	0.075000	8.5
															BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	17.5	0.00E+00	0				0.000		DAM-BIRNEY	114	0.075000	8.5
															BELOW BIRNEY	10032	0.000200	2.0
20-25 (22.5)	8.00E-04	NO FAIL (& PF)	1			1		0.0008										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000	22.5	0.00E+00	38	0.000				0.029	DAM-BIRNEY	114	0.075000	8.5
															BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000	22.5	0.00E+00	38		0.000				DAM-BIRNEY	114	0.075000	8.5
															BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000	22.5	0.00E+00	38			0.000			DAM-BIRNEY	114	0.075000	8.5
															BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	22.5	0.00E+00	38				0.000		DAM-BIRNEY	114	0.075000	8.5
															BELOW BIRNEY	10032	0.000200	2.0

LOADING		SYSTEM RESPONSE		OUTCOME					ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12) ANNUAL RISK COST ($*10**6)	(13) ANNUAL RISK COST ($*10**6)	(14) ANNUAL RISK COST ($*10**6)	(15) TOTAL/ EVENT	(16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
25-30	8.00E-04	NO FAIL (& PF)	1			1		0.0008										
(27.5)		SPILL CREST F	0.0000	F - SPILLWAY		1.0000	27.5	0.00E+00	83	0.000				0.050	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000	27.5	0.00E+00	83		0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000	27.5	0.00E+00	83			0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	27.5	0.00E+00	83				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
30-50	8.00E-04	NO FAIL (& PF)	1			1		0.0008										
(40)		SPILL CREST F	0.0000	F - SPILLWAY		1.0000	40	0.00E+00	111	0.000				0.088	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000	40	0.00E+00	111		0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000	40	0.00E+00	111			0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	40	0.00E+00	111				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
50-80	3.00E-04	NO FAIL (& PF)	1			1		0.0003										
(65)		SPILL CREST F	0.0000	F - SPILLWAY		1.0000	65	0.00E+00	180	0.000				0.048	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000	65	0.00E+00	180		0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000	65	0.00E+00	180			0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	65	0.00E+00	180				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
80-110	1.80E-04	NO FAIL (& PF)	1			1		0.00018										
(95)		SPILL CREST F	0.0000	F - SPILLWAY		1.0000	95	0.00E+00	189	0.000				0.034	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000	95	0.00E+00	189		0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000	95	0.00E+00	189			0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	95	0.00E+00	189				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0

LOADING		SYSTEM RESPONSE			OUTCOME				ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12) ANNUAL RISK COST ($*10**6)	(13) ANNUAL RISK COST ($*10**6)	(14) ANNUAL RISK COST ($*10**6)	(15) (TOTAL/ EVENT)	(16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
110-200 (155)	8.00E-05	NO FAIL (& PF)	1			1		0.00008										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000	155	0.00E+80	218	0.000				0.017	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000	155	0.00E+00	218		0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000	155	0.00E+00	218			0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	155	0.00E+00	218				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
200-382 (291)	3.00E-05	NO FAIL (& PF)	1			1		0.00003										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000	291	0.00E+00	248	0.000				0.007	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000	281	0.00E+00	248		0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000	291	0.00E+00	248			0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	291	0.00E+00	248				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
>382 (>441)_	1.00E-05	NO FAIL (& PF)	1			1		0.00001										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000	441	0.00E+00	285	0.000				0.003	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000	441	0.00E+00	285		0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000	441	0.00E+00	285			0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	441	0.00E+00	285				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
							TOTAL	0.00E+00	TOTAL =	0.000	0.000	0.000	0.000					

Annual Risk Cost(Spring Flood Events)= 0.278

LOADING		SYSTEM RESPONSE			OUTCOME				ECONOMIC DAMAGE						THREAT TO LIFE			
EVENT TYPE	EVENT PROB	RESPONSE TYPE	RESPONSE PROB	OUTCOME TYPE	RESERVOIR STAGE (FT MSL)	OUTCOME PROB	BREACH PEAK FLOW (K CFS)	PATHWAY PROB.	PER EVENT ($*10**6)	ANNUAL RISK COST ($*10**6)	($*10**6)	($*10**6)	($*10**6)	(TOTAL/ EVENT)	POPULATION AT RISK	POPULATION AT RISK	EXPOSURE PROB	LOSS OF LIFE PER EVENT
HYDROLOGIC - SUMMER FLOOD (INFLOWS IN K. CFS)																		
0-10	0.99955	NO FAIL (& PF)	1			1		0.99955										
(5)		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000	5	0.00E+00						0.000	DAM-BIRNEY	114	0.075000	8.5
									0	0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000	5	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									0		0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000	5	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									0			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	5	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									0				0.000		BELOW BIRNEY	10032	0.000200	2.0
10-15	1.50E-04	NO FAIL (& PF)	1			1		0.00015										
(12.5)		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000	12.5	0.00E+00						0.000	DAM-BIRNEY	114	0.075000	8.5
									0	0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000	12.5	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									0		0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000	12.5	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									0			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	12.5	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									0				0.000		BELOW BIRNEY	10032	0.000200	2.0
15-20	1.00E-04	NO FAIL (& PF)	1			1		0.0001										
(17.5)		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000	17.5	0.00E+00						0.000	DAM-BIRNEY	114	0.075000	8.5
									0	0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000	17.5	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									0		0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000	17.5	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									0			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	17.5	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									0				0.000		BELOW BIRNEY	10032	0.000200	2.0
20-25	8.00E-05	NO FAIL (& PF)	1			1		0.00008										
(22.5)		SPILL CREST F	0.0000															
				F - SPILLWAY		1.0000	22.5	0.00E+00						0.003	DAM-BIRNEY	114	0.075000	8.5
									38	0.000					BELOW BIRNEY	10032	0.000200	2.0
		TAILRACE EROS.	0.0000															
				F STILL B.		1.0000	22.5	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									38		0.000				BELOW BIRNEY	10032	0.000200	2.0
		PIPING CLINKER	0.0000															
				F SPILLWAY		1.0000	22.5	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									38			0.000			BELOW BIRNEY	10032	0.000200	2.0
		OVERTOPPING	0.0000															
				F - BREACH		1.0000	22.5	0.00E+00							DAM-BIRNEY	114	0.075000	8.5
									38				0.000		BELOW BIRNEY	10032	0.000200	2.0

LOADING		SYSTEM RESPONSE			OUTCOME				ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12) ($*10**6)	(13) ($*10**6)	(14) ($*10**6)	(15) (TOTAL/ EVENT)	(16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
25-30 (27.5)	4.00E-05		1			1		0.00004										
		NO FAIL (& PF) SPILL CREST F	0.0000	F - SPILLWAY		1.0000	27.5	0.00E+00	83	0.000				0.003	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000	27.5	0.00E+00	83		0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000	27.5	0.00E+00	83			0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	27.5	0.00E+00	83				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
30-50 (40)	4.00E-05		1			1		0.00004										
		NO FAIL (& PF) SPILL CREST F	0.0000	F - SPILLWAY		1.0000	40	0.00E+00	111	0.000				0.004	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000	40	0.00E+00	111		0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000	40	0.00E+00	111			0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	40	0.00E+00	111				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
50-80 (65)	3.00E-05		1			1		0.00003										
		NO FAIL (& PF) SPILL CREST F	0.0000	F - SPILLWAY		1.0000	65	0.00E+00	180	0.000				0.005	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000	65	0.00E+00	180		0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000	65	0.00E+00	180			0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	65	0.00E+00	180				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
80-110 (95)	1.00E-05		1			1		0.00001										
		NO FAIL (& PF) SPILL CREST F	0.0000	F - SPILLWAY		1.0000	95	0.00E+00	189	0.000				0.002	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000	95	0.00E+00	189		0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000	95	0.00E+00	189			0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	95	0.00E+00	189				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0

LOADING		SYSTEM RESPONSE		OUTCOME					ECONOMIC DAMAGE						THREAT TO LIFE			
(1) EVENT TYPE	(2) EVENT PROB	(3) RESPONSE TYPE	(4) RESPONSE PROB	(5) OUTCOME TYPE	(6) RESERVOIR STAGE (FT MSL)	(7) OUTCOME PROB	(8) BREACH PEAK FLOW (K CFS)	(9) PATHWAY PROB.	(10) PER EVENT ($*10**6)	(11) ANNUAL RISK COST ($*10**6)	(12) ANNUAL RISK COST ($*10**6)	(13) ANNUAL RISK COST ($*10**6)	(14) ANNUAL RISK COST ($*10**6)	(15) (TOTAL/ EVENT)	(16) POPULATION AT RISK	(17) POPULATION AT RISK	(18) EXPOSURE PROB	(19) LOSS OF LIFE PER EVENT
110-200 (155)	8.00E-06	NO FAIL (& PF)	1			1		0.000008										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000	155	0.00E+00	218	0.000				0.001	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000	155	0.00E+00	218		0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000	155	0.00E+00	218			0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	155	0.00E+00	218				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
200-382 (291)	3.00E-06	NO FAIL (& PF)	1			1		0.000003										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000	291	0.00E+00	248	0.000				0.001	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000	291	0.00E+00	248		0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000	291	0.00E+00	248			0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	291	0.00E+00	248				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
>382 (>441)	1.00E-06	NO FAIL (& PF)	1			1		0.000001										
		SPILL CREST F	0.0000	F - SPILLWAY		1.0000	441	0.00E+00	285	0.000				0.000	DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		TAILRACE EROS.	0.0000	F STILL B.		1.0000	441	0.00E+00	285		0.000				DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		PIPING CLINKER	0.0000	F SPILLWAY		1.0000	441	0.00E+00	285			0.000			DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
		OVERTOPPING	0.0000	F - BREACH		1.0000	441	0.00E+00	285				0.000		DAM-BIRNEY BELOW BIRNEY	114 10032	0.075000 0.000200	8.5 2.0
							TOTAL	0.00E+00		0.000	0.000	0.000	0.000					

Annual Risk Cost(Summer Flood Events)= 0.019

Tongue River Dam Risk Analysis — ALTERNATIVE E, BREACH — Seismic Event

LOADING		SYSTEM RESPONSE			OUTCOME				ECONOMIC DAMAGE		THREAT TO LIFE		
EVENT TYPE	EVENT PROB	RESPONSE TYPE	RESPONSE PROB	OUTCOME TYPE	RESERVOIR STAGE (FT MSL)	OUTCOME PROB	BREACH PEAK FLOW (K CFS)	PATHWAY PROB.	PER EVENT ($*10**6)	ANNUAL RISK COST ($*10**6)	POPULATION AT RISK	POPULATION AT RISK	EXPOSURE PROB

SEISMIC - NOT APPLICABLE

Tongue River Dam Risk Analysis — ALTERNATIVE E, BREACH — Static Events

LOADING		SYSTEM RESPONSE			OUTCOME			PROB	ECONOMIC DAMAGE		THREAT TO LIFE		
EVENT TYPE	EVENT PROB	RESPONSE TYPE	RESPONSE PROB	OUTCOME TYPE	RESERVOIR STAGE (FT MSL)	OUTCOME PROB	BREACH PEAK FLOW (K CFS)	PATHWAY PROB.	PER EVENT ($*10**6)	ANNUAL RISK COST ($*10**6)	POPULATION AT RISK	POPULATION AT RISK	EXPOSURE PROB

STATIC - NOT APPLICABLE

TOTAL ANNUAL RISK COST FOR ALTERNATIVE = 0.298